APPLIED ANIMAL NUTRITION

A SERIES OF COLLEGE TEXTS
IN AGRICULTURAL SCIENCE

APPLIED ANIMAL NUTRITION

The Use of Feedstuffs in the Formulation of Livestock Rations

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that the teaching of animal nutrition should bring closer together the theory of nutrition and the practice of animal feeding This gap is not adequately covered by recapitulation of the specifications and behavior in rations of the hundreds of edible products used in feeding animals Nor should we shirk our responsibility by discussing theories of animal nutrition, and leaving it for some phase of animal care and management to apply the theories to feeding practice For example, the problems of ration formulation, together with those of ingredient procurement, processing, and mixing have become so broad in scope and so intricate in application that the commercial preparation of 'balanced rations" and of specialized ration supplements is no longer merely a matter of convenience to the feeder

The present book has been designed expressly to help bridge this gap between animal nutrition and livestock feeding practice, it is an attempt to extend Fundamental Animal Nutrition into what we may call *Applied Animal Nutrition*

Students taking this course should have as prerequisites, as far as practicable, those subjects of a college undergraduate curriculum necessary for an understanding of fundamental animal nutrition, as well as many of those that deal with animal care and management

The subject matter of the text can partly be deduced from the paragraphs above The author, in attempting a critical consideration of feedstuffs and their use, accepts on the one hand the facts presented and discussed in Animal Nutrition, and on the other, presumes that livestock feeding practice is a part of the subject of animal management He also assumes that a catalogue of feedstuffs is an important part of the subject matter of reference books on feedstuffs rather than a desirable feature of a text dealing with problems of the assembly of nutrients into rations But he does believe firmly, that to present a coherent and reasonably complete treatment of *Applied Animal Nutrition* he cannot be bound by traditional subject limitations

The reader will find the subject matter treated under four main sections, plus an appendix The first section is devoted to definition and critical appraisal of the terms and expressions used in describing feedstuffs Section II deals with the nutritional requirements of ani-

mals, with special attention to the biological basis for feeding standard data. The nature of feeding standards and their limitations as guides in ration formulation are also considered in some detail. Section III features a classification of feeds. The discussion of the properties and functions of key feeds is intended to establish a sound basis for feed substitution in ration formulation. A classification of roughages according to available energy is a feature of this Section.

The last Section (IV) has to do with the problems of ration formulation. The translation of feeding standards into terms of meal mixtures, and the development of the concept of flexible formulae for meal mixtures, mineral mixtures; and mixed supplements intended as all, or as a part of the rations of farm livestock (cattle and swine) receives careful consideration in this section. It is through such formulae that the facts of nutrition and the characteristics of feeds are eventually brought together in terms that are immediately useful in feeding practice.

Finally pertinent comments on feed legislation and a selected table of feed composition appear as an appendix.

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SECTION I WHAT ARE FEEDSTUFFS?

The dilemma facing the author of a text about feedstuffs and their use in practice is, where to begin. Seemingly, no matter where he makes his start, there is something that should already have been explained or considered. A part of this difficulty arises because some of the same terms are used to describe animal needs that are employed in the description of the properties of the products used to meet these needs. And so it may be logical to deal first with the definitions of a variety of terms, all of which eventually you will need to understand. We shall interpret "Definition of Terms" broadly to include, where it seems desirable, much more than names or expressions. To make the definitions useful it may be necessary to expand them into somewhat detailed discussions of the significance and use of the term under consideration.

Not all of the nutritional terms used in this book, however, will be thus defined, for we shall assume that the reader already has at least an elementary knowledge of fundamental nutrition and hence of the biochemistry, physiology, bacteriology, and mathematics that underly this subject. Perhaps we may sum up the whole matter by saying that this section will deal with what feedstuffs are, how they are described, and what significance is to be attached to their descriptions in applied livestock feeding.

In this section it is not our intention to catalogue by name the hundreds of feeding stuffs known and used in the rations of animals Our objective is rather to consider a number of the terms, particularly those other than the name, that we employ in describing feeds and to examine what each of these really tells about the nutritional properties of the product Some of the terms are applied to all feed stuffs as for example, the proximate analysis, *either complete or in part while others are applicable only to specific or perhaps to a limited group of products*

CHAPTER 1

Terms and Definitions Used in Connection with Feeds

Names

YOU SHOULD not infer from the comments we made in the introduction to this section that the *name* of a feed is of no importance. On the contrary, an experienced livestock feeder who knows the feeding properties of a given feedstuff can identify it *by name alone* and use it in its proper place in the ration. For example, he might not be able to distinguish easily a sample of finely ground oats from one of ground barley. If, however, the samples were identified by *name*, he would have no difficulty in using the two products properly, since their *names* would identify for him at once the well-known nutritive characteristics associated with each feed.

For official description the name serves in the same way that the name of any other product serves, either as a complete description of a unique product or as the starting point of a more detailed characterization. Feed control legislation usually includes the official name and often some further descriptive information for all recognized feeds. Such facts may or may not have direct relation to feeding value.

In this connection let us cite an example of the name problem. Barley is used for malt in the production of beer; not all barley is suitable for this purpose and may instead be used as human or animal

food In Canada barley sold for animal food may be graded and sold as "feed' barley Insofar as the barley in the product is concerned it is the unaltered seed of the barley plant It is "feed' barley rather than "malting" barley because of its characteristics as to variety and quality The feeder who uses it, however, may think and speak of it as "barley feed'

But 'barley feed" is the official name of another product—the mill-run offal from the manufacture of pot and pearl barley for human use It is, in fact, the hull, the germ, and a part of the outer coating of the barley kernel or groat

Were it not for the official names and definitions of the products, the feeder might not realize that rations guaranteed to contain "barley feed' are not made with entire barley but instead contain a by-product of relatively low energy value

Similarly, the product officially known as "rice feed' is a mixture of rice bran, rice embryo, and rice polishings This product is sometimes offered to a feeder as "rice meal," the term used in the rice mill to designate this residue from the production of polished rice from brown rice Since barley meal is ground barley, the feeder may erroneously assume that this rice meal is ground rice Unlike barley feed, rice feed has an energy value actually higher than ground rice, since it is a low-fiber, high-fat product

Names, together with the additional descriptive information in the official records, may adequately serve to identify products commercially, but unless the feeder knows whether or not the parts of the feed included in the material are nutritionally equivalent to the whole seed, the name and official description are of little use in indicating feeding properties of by-products

Occasionally products that are quite local in occurrence are referred to by their users in terms that are misleading as to their nature In some buckwheat growing areas this grain is milled by cracking off the outer, woody, black hull, which may be used as packing material, since it has no feeding value, while the inner kernel is fed to livestock or further milled into flour Local stock feeders often refer to this kernel as buckwheat, and feeders in the area are familiar with the nature of the product Difficulty and mis-

understanding arise, however, when these feeders request from an outsider information regarding the use of "buckwheat."

Then there is the authentic case of the farmer who complained to the farm paper that the advice given him about alfalfa hay was quite wrong; that when he fed his alfalfa as directed his cows did very poorly. In a postscript he asked, as an afterthought, where he could sell the seed he had threshed "off this hay."

And so names are important when dealing with feedstuffs if for no other reason that they may help to identify products sufficiently that two people can be sure they are talking about the same feed. To be most useful in this respect and to avoid confusion, take care to use the correct official name when referring to a feed. The descriptive material one should expect to find given with an official definition of a feed will normally include its origin, source or parent material, pertinent information relative to the processes by which it is produced, and any restrictions or limits as to the makeup, if such apply. For example, "Feeding Tankage is the wet-rendered or dry-rendered, or both, residues from animal or poultry tissues suitable for livestock feeding and containing not less than 50% of crude protein; it shall not contain more than 35% of blood; if it bears a name descriptive of its kind, composition or origin, it shall correspond thereto; when wet-rendered it shall be tanked under live steam." Or, again, "Corn Gluten feed is that part of commercial shelled corn that remains after the extraction of the larger part of the starch and germ by the processes employed in the wet-milling manufacture of cornstarch or corn syrup. It may or may not contain either corn solubles or corn oil meal." *

The official names and definitions of feedstuffs that are regulated in feed legislation for both the United States and for Canada are given in Appendix II of this book.

Official definitions, especially those that contain specific restrictions as to purity or admixture, may vary in different local jurisdictions. Such "definitions" and their specific restrictions are "official" only in the locality where they apply; as, for instance, in several of the States, which have feed control laws that are not uniform.

* *The Feeding Stuffs Act* (1952), Canada Dept. of Agriculture.

We should note a further limitation on the usefulness of the name of a feedstuff The name cannot give the feeder direct information indicative of feeding value unless he knows the nutritional properties of the components indicated by the name to comprise the feed, such as wheat germ meal, or unless he is familiar with the consequences of the processing that the definition indicates has been involved in its production, such as dry-rendered, wet-milling, etc

Feeding Stuffs

This term is, in general, synonymous with feed, food, or fodder, although it is broader than these terms in covering all materials included in the diet because of nutritional properties It embraces not only the naturally occurring plant or animal products and the by-products prepared from them, but also chemically synthesized or otherwise manufactured pure nutrients or prepared mixtures of them used as supplements to natural foods Thus, while wheat germ meal is a livestock feed or a human food, thiamine hydrochloride is a pure nutrient, which may be chemically synthesized and used as a supplement to feeds It is not a feed but it is a foodstuff A feeding stuff therefore is any product, whether of natural origin or one artificially prepared, that when properly used has nutritional value in the diet

Ration; Diet. A ration is a 24 hour allowance of a feed or of the mixture of feeding stuffs making up the diet The term carries no implications that the allowance is adequate in quantity or kind to meet the nutritional needs of the animal for which it is intended It merely refers to a daily allocation of provisions and is the usual basis for food accounting in the armed forces and in institutions

Some confusion occasionally arises as to the meaning of the two terms *ration* and *diet* Is there any distinction between them? According to Webster a ration is "a fixed daily allowance of food for one person (or one animal) in an army or navy" A diet is "what a person or animal usually eats and drinks, daily fare" The distinction made by some in using *diet* as applied to human food, and

ration with animal feeding is not logical, especially since we refer to the rations of laboratory animals as diets. In the sense of their meaning, the terms are synonymous and are so used in this book.

The introduction of the term *ration* into livestock feeding language was accompanied by a less precise definition of its meaning. The feeder was usually as much interested in a nutritionally adequate ration as in a statement of a quantity of some food. To meet this need the term *balanced ration* was coined to refer to a feed mixture just sufficient to meet the 24-hour requirements of a specified animal; the *balance* referred to the proportion of carbohydrate, fat, and protein in the ration.

We recognize, of course, that some hundred or more nutrients are known which may be involved in an adequate diet, and that a ration balanced as to the primary or energy yielding nutrients may still be sadly deficient for the nourishment of the animal.

Furthermore, in practical husbandry, rations are not prepared for individual animals; rather some mixture of feeds is prepared and portions doled out to animals of the same feeding group; or else the mixture may be self-fed to groups of animals of the same feeding category.

The original implication of the ration as a 24-hour allowance of food for one animal was never compatible with the practical use of feedstuffs. Ration, however, appears to be firmly established in the feeding lingo, but its definition has undergone an important change. As most often used since about 1940 in the feed trade and by the feeder, ration or even balanced ration refers to a mixture of feedstuffs prepared for the feeding of some specified class or group of animals and intended to constitute either the entire dietary allowance or some definite and specified portion of it.

When the mixture is referred to as a balanced ration the reference implies that the mixture is nutritionally adequate for the feeding of the animals specified when used according to recommendations. These recommendations are important since the ration as it is may not be a complete ready-to-feed mixture. It may require the addition of basal feeds, as in the case of a supplement; or may be

intended for feeding over a restricted period only, as in the case of medicated mixtures, or it may be suitable for feeding in conjunction with forage of a certain kind, as in the case of cattle feeds

Basal Feeds

This term appears to be of Canadian origin and was first used as a designation of the whole group of grains and their by-products whose protein content does not exceed 16% or their fiber 18%. The feedstuffs of this category form the basis of normal livestock meal rations

Nutritionally, basal feeds are primarily concentrated sources of energy, being especially rich in starches and sugars They have been described as carbonaceous concentrates In everyday feeder's language they are the low protein concentrates, such as corn, barley, oats, wheat, and the by-products milled from them that do not contain enough of the embryo or of the gluten layers to appreciably increase the protein of the feed over that of the parent grain

Basal feeds average between 10 and 14% crude protein and something less than 5% of ether extract The chief gross difference between basal feeds, which is of significance in their practical use, lies in their digestible energy content, which, in turn, is likely to be inversely proportional to their crude fiber content

Inasmuch as feeds of this category normally constitute from 60 to 90% of practical livestock rations (exclusive of roughage), it is evident that an important consequence of substitutions between these feeds is a change in the useful energy value of the ration, and hence in the *quantity of the ration that must be fed to meet the animal's requirements* Undoubtedly more feeding problems are traceable to failure to meet energy requirements than to any other single cause

Supplements

Feeds of this type are concentrated sources of protein or of some mineral element, or of some particular vitamin A mixed protein

supplement is by convention a mixture of feeds that carries 30% or more of protein. However, single feeds that contain 20% or more of protein are included in the supplement category. Any mineral or vitamin carriers added to the ration are normally referred to as supplements.

The term supplement is itself descriptive of its definition. For example, in order to properly balance the basal feeds, additional protein must often be incorporated in the final mixture. This is normally done by adding feeds that are richer in protein than the basal feeds. Consequently, such feeds are commonly referred to as protein supplements.

Some protein supplements are high in protein because by nature they contain very little carbohydrate. This would be true of many animal by-products such as meat meal, or liver meal, or dried milk. We shall also find marine products such as fish meal high in protein for the same reason. In both instances the fat of the original carcass has been largely removed. Nevertheless, with some fish meals there may be appreciable amounts of oil remaining in the meal, which not only dilutes the protein but may limit the use of the product, as we shall point out later.

On the other hand, most of the high protein feeds are of plant origin and contain a high concentration of protein because some parts of the original product have been removed by milling. Thus, we find the protein supplements from the oil-bearing seeds are nothing more than the seed from which the oil has been extracted, with the result that the residue carries relatively more protein than it did originally in the whole seed. Another group of protein supplements are high in protein because the starch has been removed from the original seed.

Concentrates

Technically all feeds supplying primary nutrients (protein, carbohydrate, and fat) are classed as concentrates if their crude fiber content does not exceed 18% (see Roughage below). In the feed trade, however, the term concentrate has been almost universally used

to indicate commercially prepared supplements In this sense the term concentrate refers to a concentration of proteins, or of minerals, or of vitamins in excess of those found in the basal feed Such concentrates are usually mixtures, and these concentrate mixtures frequently supply several of the individual nutrients with which the basal feeds must be fortified in order to make adequate rations There is seldom any difficulty in interpreting the terms *concentrate* and *supplement* because the context in which they are used indicates what they mean

Roughage

In farm usage roughage is normally considered to be material making up fodder such as hay, silage, pasturage, etc The distinguishing characteristic of roughage is usually a high fiber content For hays this frequently runs between 25 and 30% of the dry weight

There is, however, another group of feeds that in physical appearance might be classed as concentrates, but which nevertheless are nutritionally more like roughages, as they are high in fiber and relatively low in useful energy For example, it seems inconsistent to class alfalfa hay as roughage, and the meal made from it by grinding, as a concentrate It is also difficult to justify the practice of labeling as a concentrate oat hulls or oat feed in spite of the fact that they are a part of ground oats When any of these products are sold unmixed with other feeds there is no particular difficulty about their feeding value When however, they are used as ingredients in "balanced" meal rations, mere statement of their presence by name in the list of ingredients may fail to warn the feeder that a low energy product is involved

One solution of this problem has been put into effect in Canada where by definition in the *Feeding Stuffs Act* roughage is any material suitable for feeding livestock which contains more than 18% crude fiber Thus, in Canada, such products as alfalfa meal, ground oat hulls, oat feed, some samples of corn bran, oat mill feed, some grain screenings, etc., are actually classified officially as roughages,

even though their common form might lead one to think of them as concentrate feeds.

Feed Processing Terms

Mash or Meal. This is a feed manufacturer's term for a ration or feed mixture in which all of the ingredients are ground. Mash is more often used in referring to poultry rations than to livestock rations; for the latter the term meal is used rather than mash. Occasionally, however, the term mash is used locally by feeders to refer to a quantity of a feed that is prepared for feeding by moistening with hot water (viz., a bran mash). The term is sometimes loosely employed by a feed manufacturer in designating a feed mixture in which some flakes or rolled ingredients are included with the ground materials.

Flakes. Unground grains or the groats from grains are sometimes prepared for feeding by crushing or rolling (between rollers). The product so treated may be referred to as rolled (as in the case of "feed rolled oats") or as flaked (as in the case of "flaked wheat"). With small, hard kernels such treatment may increase their digestibility somewhat, merely by ensuring that all of the kernels are at least broken open. The process has no other nutritional value, and it is used primarily to change the physical nature of the ration in the hopes that it may induce greater feed consumption.

Pellets. Feedstuffs, after grinding and moistening (called *tempering* in the feed mill) may be forced under pressure through perforated dies. As the strings of material extrude through the die they are cut off into short lengths. These small, pressed feed particles are called pellets, and feeds or feed mixtures so prepared are said to have been pelleted. Nutritionally, this method of preparation, has some advantages over the mere grinding of the grains. With some feedstuffs and with some classes of animals there may be a tendency for coarser materials in mixtures to sift out or to be picked out from the finer ingredients. Such segregation becomes important in the

case of mixtures where small quantities of purified nutrients are added as supplements, and where an even distribution must be maintained through the batch of feed for satisfactory feeding results It is also claimed by some that when pelleted feeds are offered to livestock there is less wastage, particularly of feed that has been spilled from the feeder, because the animals can recover spilled pellets more easily than spilled ground feed

There is no doubt that pelleting tends to improve the physical nature and hence the acceptability of feed mixtures that contain powdery substances Animals dislike powdery feeds and may not only waste considerable quantities of such materials when they are offered, but may voluntarily reduce their feed intake appreciably

There is no satisfactory evidence that pelleted feeds are any more nutritious per pound of material consumed than those that are fed without such processing If, however, by such treatment dustiness is reduced and animals can be induced to consume larger quantities of the feed, it may be worth its cost

Pelleting has also been used to simplify the problem of the feeder who wishes to use his own farm grown grains that are unground, but who must also employ certain commercially prepared materials that are ground Feed manufacturers will frequently supply feed mixtures in pelleted form, which may be mixed with unground farm grains into combinations that will not separate out

One of the problems in pelleting feeds is to prepare the pellet in a firm enough form to resist breaking and crumbling on handling Molasses incorporated in the feed to the extent of 5 to 10% will usually keep the pellets from crumbling More recently sodium bentonite to the extent of about 2% has been incorporated into such feeds, where it is effective in making a firmer pellet

Crumbles Crumbles are crushed pellets The product may or may not have been sifted to a uniform size of particle When they are sifted the fines are returned for repelleting and subsequent crumbling

The process of crumbling is employed for two purposes the first one is that it may speed up production Feed mixtures can be proc-

essed into relatively large-sized pellets, which are then crumbled. The manufacturing cost of producing a large pellet is much less than that of producing a small pellet, and consequently the process is attractive from the manufacturing standpoint. The second reason is because it has been found that some classes of stock prefer a fine pellet and perhaps one of irregular shape. Crumbles seem to be the answer to this problem since the feed has all the advantages of being dust-free and at the same time is granular in form.

Nutrient

A nutrient is defined by Morrison as any food constituent, or group of food constituents of the same general chemical composition, that aids in the support of animal life. We must interpret this definition somewhat more broadly than was originally intended, because we now have to include substances that are not of food origin. And so while foods are parcels of nutrients usually mixed with non-nutrient material, a complete ration may be more than a combination of foods. It may include synthetically produced vitamins and chemically prepared inorganic salts, or perhaps amino acids recovered from hair. What animals eat in terms of the products actually consumed is fundamentally of much less importance than is the quantity and assortment of the nutrients furnished to the body through the rations made available to them.

One cannot be sure today that a list of the presently recognized nutrients found in feeds, or found in animal tissues, represents a complete list of the operating needs of the body. For practical purposes, however, we do know what the majority of these nutrients are, and enough about most of them so that we understand what their general functions are, and consequently why they must be supplied to the animal.

In the practical feeding of animals we recognize that some of the nutrients are non-specific in function and thus may be essential only as members of a group of nutrients having similar functions. However, even where some nutrients can be classed together on the basis of certain common properties, individual members of these

groups may have specific functions not duplicated by other members of the same group. In order to systematize a consideration of the nutrients you may find it useful to look at them grouped into categories, which have nutritional, or at least unique descriptive characteristics. Such a listing is shown in Chart 1-A.

In this list only the 12 essential amino acids are detailed and no attempt is made to indicate the wide assortment of fatty acids, or the different sugars and other carbohydrates that the chemist is able to isolate from feedstuffs. Nor is the list of vitamins as complete as present information would permit. The list is intended rather to include those nutrients with which the feeder may have to concern himself in the preparation of satisfactory rations.

We have attempted to classify the inorganic elements into those that often have to be added in ration formulation, and those that are usually abundant in any diet. The feeder is cautioned that this part of the classification cannot be made fixed because of differences between geographic areas in both qualitative and quantitative occurrence in feeds of some of the elements.

It is difficult to place these few mineral elements in any order of priority or importance. In point of quantity calcium and phosphorus will stand first, if we assume that common salt is to be supplied as a matter of routine and quite independently of any quantities of sodium and chlorine that may be in the feedstuff. Information concerning the content of feeds in iron, cobalt, and copper will be desirable insofar as the required elements are concerned, but there may be some doubt as to whether one need worry about the iodine content of any of the feedstuffs. Evidence of the need for supplemental iodine is quite clear for young farm animals born with the well known symptoms of iodine deficiency. Since few animals subsist entirely on feeds grown in a particular district where the animals themselves are kept, knowledge of the iodine content of the feeds of such districts is of relatively little help in predicting the need for iodine supplementation. Furthermore, supplementation with iodine of the rations of pregnant females is largely a routine matter wherever goiter is found, and it is usually accomplished by purchasing iodized salt.

CHART 1-A *Showing Nutrients to Be Considered in Ration Formulation*

Main groups	Subgroups	Nutrient group	Specific nutrients
Nitrogenous	Proteins	Amino acids	Lysine, tryptophane, histidine, leucine, phenylalanine, isoleucine, threonine, methionine, valine, arginine, glycine, glutamic acid
	Non-protein	Amino acids	
Non-nitrogenous	Lipides	Neutral fats	Non-specific sources of energy
		Fatty acids	Linoleic, linolenic, arachidonic
		Sterols	Mother substance of Vitamin D
	Carbohydrate	Starches & sugars	Non-specific sources of energy
		Cellulose	Essential food for some micro-flora as cellulose
		Hemicellulose	
	Other	Lignin	Not a nutrient—a hindrance to bacterial breakdown of cellulose
Vitamins	Fat soluble	Vitamin A	Carotene
		Vit. D_2 (plant origin)	Calciferol
		Vit. D_3 (animal origin)	7-dehydrocholesterol
		Vitamin E	
		Vitamin K	
	Water soluble	Vitamin B-complex	Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, Vitamin B_{12}
Inorganic elements	Essential	Often required as supplements	Calcium, phosphorus, sodium, chlorine, iron
		Needed as supplements in specific geographic areas	Iodine Cobalt
		Usually abundant in normal diets	Potassium, magnesium, manganese, zinc, sulfur, copper
	Non-essential	Toxic	Fluorine, arsenic, selenium, molybdenum

We shall deal with the question of the quantities of the several nutrients needed by various animals in a later section

Enzymes

An enzyme is defined as one of a number of complex organic substances capable by catalytic action of transforming some other compound In the sense that it is of concern to us here, enzymes are the biological units that make possible the assembly and/or dissociation of the chemical units involved in the changes that foods, nutrients, and tissues undergo in their metabolism All chemical changes within the body are enzyme-catalyzed, from which it follows that partial or complete enzyme failure is at once reflected in deranged metabolism

There is a direct relation between enzymes and nutrition Enzymes are primarily combinations of amino acids, some of which, of necessity, are of dietary origin Since they must function continually, the essential nature of dietary protein is obvious

Perhaps because digestive ferments are so often cited as examples of enzyme activity, enzymes have been thought of as liquid We should note, however, that practically all cell proteins are constituents of active enzyme systems In fact, it is doubtful if any large part of the protein of the cells should be considered as primarily structural material For example, the musculature of the body is essentially an enzyme system

Muscle is about 75% water Of its dry substance some 80% is protein, most of which consists of the enzyme system actomyosin Thus, for practical purposes the dry weight of muscle, and consequently a large part of the weight of the body is an enzyme system, whose *function* is to facilitate the removal of phosphorus from its position in the energy rich adenosine triphosphate, thus releasing energy for metabolic purposes In this action the physical shape of the actin part of the actomyosin changes from globular to fibrous form by undergoing successive hydration and dehydration When these muscles are attached to bones, this change from the short globular form to the long fibrous form causes body movement In

the meantime, the adenosine triphosphate is restored by the addition of more phosphorus to the depleted adenylic acid molecule. The energy needed to effect this phosphorylation comes from dietary carbohydrates, fats, and proteins. Thus is the potential energy of foods put to work.

The relation of this enzyme system to protein nutrition is clearly evident on examination of the make-up of the enzyme myosin. Amino acids account for some 70% or more of rabbit myosin as follows:

Cystine	1.39
Methionine	3.40
Serine	3.57
Threonine	3.81
Tyrosine	3.40
Aspartic Acid	8.90
Glutamic Acid	22.10
Arginine	7.00
Lysine	10.30
Histidine	1.70
Tryptophane	0.82
Glycine	1.90
Alanine	5.10
	73.39%

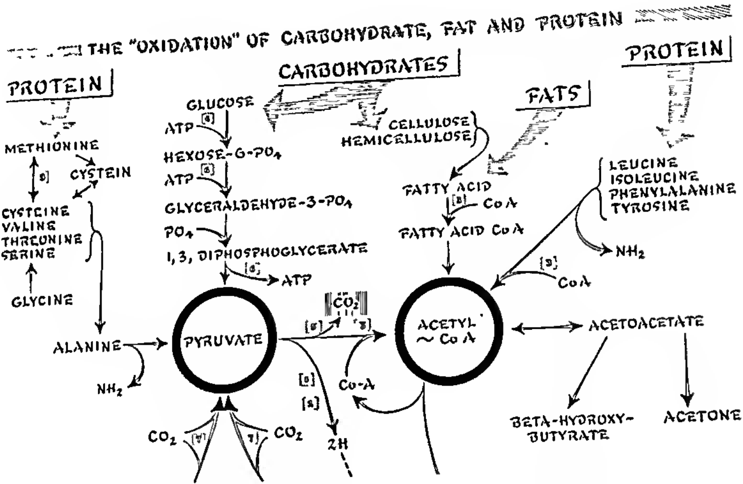
While enzymes themselves are amino acid complexes, the co-enzymes and the enzyme activators making up the other part of the active enzyme systems may involve mineral elements and/or vitamins.

Enzyme systems vary considerably in their complexity. The component parts of the system acting on a substrate, such as pyruvic acid for example, include:

A. Substances necessary to produce a suitable environment in which the reaction can proceed. Here we have water, materials to establish the correct *p*H, a suitable redox potential, and an appropriate ion concentration. This requirement is not very specific and the parts of it are not a part of the co-enzyme.

B. A protein, which is the enzyme or apoenzyme. This is inactive without its specific co-factors.

C. Co-factors, including specific inorganic divalent ions (magnesium, calcium, manganese, cobalt and zinc); and specific organic


THE "OXIDATION" OF CARBOHYDRATE, FAT AND PROTEIN
PROTEIN
CARBOHYDRATES
FATS
PROTEIN
METHIONINE
CYSTEIN
CYSTEINE
VALINE
THREONINE
SERINE
GLYCINE
ALANINE
NH2
GLUCOSE
ATP
HEXOSE-6-PO4
ATP
GLYCERALDEHYDE-3-PO4
PO4
1, 3, DIPHOSPHOGLYCERATE
ATP
PYRUVATE
CO2
CO2
CO2
2H
Co-A
CELLULOSE
HEMICELLULOSE
FATTY ACID
CoA
FATTY ACID CoA
ACETYL ~ CoA
LEUCINE
ISOLEUCINE
PHENYLALANINE
TYROSINE
NH2
CoA
ACETOACETATE
BETA-HYDROXY-BUTYRATE
ACETONE

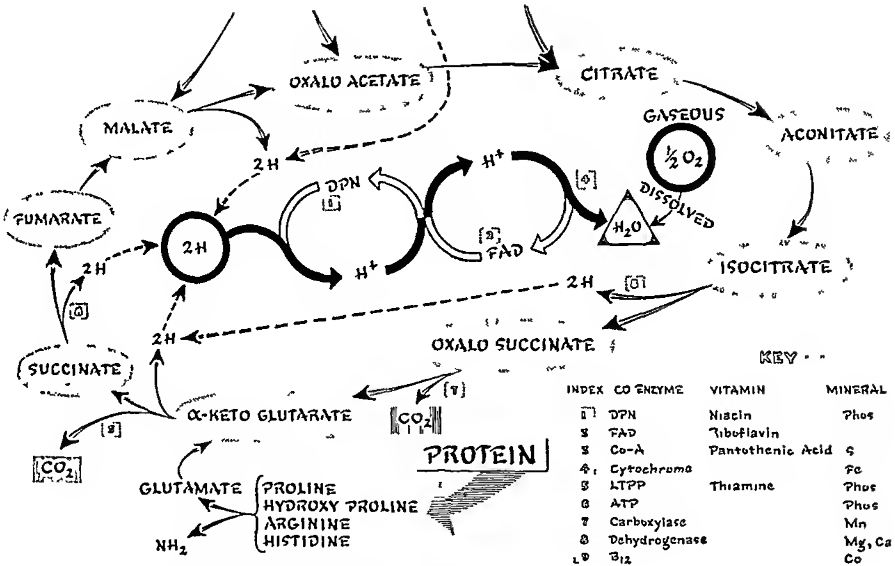


Fig. 1-1. *Some important pathways of energy metabolism*

compounds—the co-enzymes These latter are highly specific and are often complex molecules in which one of the Vitamin B-complex members is involved (such as thiamine pyrophosphate or in the pantothenic acid containing co-enzyme A)

Examples are well illustrated in the case of the "tricarboxylic cycle" of energy metabolism Normal pyruvic acid metabolism in which this product is oxidized to CO_2 and H_2O can proceed only in the presence of thiamine, pantothenic acid, riboflavin, and niacin, catalytic amounts of some C_4 dicarboxylic acid (as oxalacetic acid); some divalent ion (such as Mn^{++} or Mg^{++}), inorganic phosphate to form the phosphate ester linkage between apoenzyme and coenzyme, some hydrogen transport system (as dipyridal neucleotide or a flavo protein), and oxygen

The pantothenic acid is a part of co-enzyme A necessary to condense acetyl phosphate with oxalacetic acid, thiamine is necessary for the oxidative decarboxylation of pyruvate, nicotinic acid is a part of the co-enzymes di– and tri-phosphopyridine neucleotide needed for the dehydrogenation of iso citric and malic acids, and riboflavin is a component of the flavo-protein enzymes, which appear to be the hydrogen acceptors in the conversion of succinic to fumaric acid (see Fig 1-1)

We should point out that while certain metabolic disorders may yield to the administration of one or more of the B vitamins, these vitamins are not active by themselves To relieve the syndrome indicative of their deficiency, the vitamins must be incorporated into larger molecules, which may then function as coenzymes in some of the metabolic machinery It has been suggested that the specific function of the vitamin is to form the protein-coenzyme bond

There are a large number of separate reactions involved in the metabolism of carbohydrates, fats and proteins, but the types of reactions are relatively few Nevertheless, each vitamin involved appears to be specific for a given type of reaction

This brief consideration of the make-up of some of the enzymes involved in the metabolism of food should clarify several points regarding the critical need for amino acids, mineral elements, and vitamins, as well as explain why a single deficiency might be reflected

in a wide variety of clinical symptoms; and, conversely, why any one of several possible deficiencies might result in the same clinical picture. It is the difficulty in identifying the exact deficiency that is so often misleading in the diagnosis of the cause of some condition.

For example, you will note from the chart of energy metabolism that the reaction between the "active acetate" (acetyl-Co-A) and acetoacetic acid is reversible. If there is any disturbance in the smooth operation of the "Krebs Cycle," the fate of acetyl-Co-A is likely to be toward the formation of acetoacetic acid instead of a condensation with oxalacetic acid to form citric acid. The increased production of acetoacetic acid results in the formation of acetone, which is then excreted both in the urine and by respiration to relieve the acidosis that the body cannot tolerate. Here we find, then, that the deficiency of any one of several of the B vitamins, or of phosphorus, or of certain minerals, or of enough carbohydrate to maintain the necessary oxalacetic acid (especially in the case of high fat intake), or the presence of an enzyme poison such as fluorine, might lead to secondary acetonemia. The diagnosis of acetonemia is relatively easy—but to spot its specific cause is another matter. Obviously a single criterion of faulty metabolism is seldom a reliable index of its possible nutritional cause.

Toxicity

At first thought this may seem to be an anomalous term to use in connection with a consideration of nutrients or even with feedstuffs. One might argue that if a nutrient is any edible material that aids in the nourishment of an animal, such material can hardly have toxicity as one of its attributes. Nevertheless, there are substances that when used at certain levels are essential to complete nutrition, but above those levels are harmful enough to be classed as toxic.

The difficulty lies in the definition of toxicity. The word is of Greek origin and denotes a poisonous substance. And the common implication is that the consequence of poisoning is death. Veterinarians often qualify the term with such adjectives as mild or acute

to denote degrees of damage to the body's functioning that may be involved

In nutrition there are a number of situations where *toxic* seems the best descriptive term available and yet where *poisonous* would not be a synonym For example, it is generally accepted that linolenic acid is an essential nutrient Its complete absence from the diet for a sufficiently long period of time leads to the death of the animal This fatty acid, however, is one (perhaps the only one) that causes "flavour reversion," which is characteristic of some edible lipides Heating of fats to cause a destruction of much of this acid through *polymerization* is sometimes resorted to, and we now know that one or more of the resulting products, probably cyclic monomers, when ingested even in small amounts (i e , the order of 2% of the diet) will cause the death of young rats In smaller concentrations or with older animals the only clinical result may be a reduction of feed intake plus a decline in the gains per unit of food eaten These products of the heat polymerization of trienoic fats are conveniently termed toxic, meaning in usual cases that they interfere with normal food metabolism They are not toxic in the sense of being corrosive poisons They are toxic in the sense that they inhibit an enzyme system which otherwise would effect degradation of some molecule to useful metabolic products, or permit the molecules to be harmlessly discarded (i e , a detoxifying reaction) Such materials are often called enzyme poisons

If we pursue this line of argument far enough, we arrive at the point where we must conclude that an essential nutrient such as a vitamin may cause toxic effects by its absence! And here, of course, we come to the justification for the term *deficiency disease*

However, it is in another sense that the term toxic must sometimes be used with feedstuffs Some forage plants normally contain at certain periods of development *cyanogenic substances* that render the forage nutritionally harmful The Sorghums, Johnson s (quack) grass, and Sudan grass are among those that may contain high con centrations of glucosides, which, in the digestive tract of the animal, may be broken down by enzymes of the forage itself to yield free prussic acid in toxic amounts Young forage of these species and

also forage following wilting or after a severe check of growth, as from frost, is more dangerous than other samples. Cattle and sheep are especially susceptible to damage from such forages and may die very quickly after eating them.

Most of the cases of toxic nutrients or feedstuffs seem to be associated with one or another of four mineral elements. *Molybdenum* is entirely a forage problem. Forage raised on some soils carries enough molybdenum to interfere with utilization of dietary copper by the animal. This effect appears to be its only association with toxicity. It is not required by the animal, and in the presence of adequate copper is readily eliminated without any harmful effects. With inadequate copper, ingested molybdenum replaces some phosphorus in the bone complex, leading to thin and fragile bones; but most of the toxic symptoms are those of copper deficiency. The antidote is an increased copper intake.

Selenium is another mineral element that in certain geographic regions becomes a nutritional problem. Both the forage and the seeds from the plants grown on selenium-containing rocks are dangerous as livestock feeds. In South Dakota, Montana, and Wyoming there are rather extensive areas of shale soils that contain dangerous levels of this mineral element. Ingestion of selenium causes alkali disease, sometimes also called blind staggers and bob-tailed disease. One general characteristic of early clinical symptoms is a loss of hair from the mane and tail of horses, the switch of cattle, and the body hair of swine. Many severely affected animals die or have to be destroyed, although if removed soon enough from the hazard areas they may recover.

From the toxicity standpoint the mineral element most likely to be a problem in concentrate mixtures is *Fluorine*. Here we have a substance that some believe to be a desirable "nutrient" in small amounts (of the order of 1 p.p.m. of the dry diet), but which when ingested in larger amounts (of the order of 30 p.p.m. or more) may show definite clinical evidence of toxicity. Species differ somewhat in their tolerance to fluorine intake. We do not have to be much concerned with the fluorine content of concentrate feeds that are by-products of plants, since plants that pick up fluorine from the soil

concentrate it more in their leaves than in their seeds Thus the feeder should give some attention to the fluorine content of forage in areas that may be contaminated, but far more important he should know the fluorine content of mineral supplements, particularly those that are used to supply phosphorus Fluorine is a likely component of all rock phosphates that are used for livestock feeding, and fluorine is also found in feeding bone meals In the case of bone meal the fluorine content appears to be increasing with time, probably because of the fact that more and more livestock from which the bones are derived have been fed fluorine-containing phosphates in the course of their lives Thus meat animals that can tolerate for fairly long periods of time a high fluorine content often receive rations in which the phosphorus is provided in fluorine-containing rock phosphates There may be no particular economic damage to these animals, but their bones eventually find their way into feeding bone meal, and thus animals that are fed bone meal as a source of calcium and phosphorus receive, occasionally, undesirable amounts of this toxic element

There has, as yet, been no defense found against the harmful effects of the ingestion of excess fluorine and, consequently, the only safe course is to avoid its presence in the ration

The *Arsenic* problem is usually one of accidental ingestion except for the use, principally with poultry, of medicated feeds or supplements where an arsenic compound is sometimes one of the materials employed Some arsenicals have been found to have antibiotic-like effects in growth stimulation of young animals

No definite discussion of food toxicity is in order in this book and the comments above which arose out of an attempt to define *toxicity* in applied nutrition are more by way of illustration than of a guide to the animal husbandman The feeder should be aware of the possibility that some feedstuffs may under some conditions be correctly classed as *toxic* in the sense here used

CHAPTER 2

The Proximate Analysis of Feeds

FOR A considerable number of nutrients that are required by animals there are direct chemical procedures from which we can establish the potency of foodstuffs with respect to these nutrients. Such data present no particular problem insofar as the use we can make of the figures is concerned.

There are, however, a number of cases in which we isolate feed fractions chemically, but where these fractions are combinations of nutrients that have some common property permitting a chemical analysis of the group. The nutritional significance of such nutrient groups is dependent on a number of factors that are not indicated by the figure representing the proportion of the feed comprising the group. For example, the several feed fractions separated by the proximate analysis are in all cases combinations of nutrients and consequently, of varying nutritional significance.

The proximate analysis is probably the most generally used chemical scheme for describing feedstuffs, in spite of the fact that the information it gives, in many instances, may be of uncertain nutritional significance; if, indeed, it is not misleading. We should, therefore, consider in some detail the nature, the peculiarities, and the limitations of the proximate analysis as a description of the nutritional properties of feedstuffs.

This scheme of analysis was devised by workers at the Weende Experiment Station in Germany. According to it a feedstuff is partitioned into six fractions as follows:

Water
Ether extract
Crude fiber
Nitrogen free extract
Crude protein
Ash

When a chemist is asked to run a standard feeding stuffs analysis on a given food he proceeds to determine, chemically, five of these proximate principles The last one, nitrogen free extract, he then determines by difference The sum of the crude fiber and the nitrogen-free extract represents the total carbohydrate of the feed

This plan of description groups together a variety of substances based largely on some common chemical characteristics It is not, as is sometimes erroneously supposed, an analysis of the nutrients of the food Each of the components except water, represents a combination of substances some of which are nutrients or combinations of nutrients, and some of which are not of any nutritional value to the animal at all

Water

Water, the simplest of all substances in foods, is not the simplest to determine Usually it is recorded as the loss in weight of a sample after oven drying to a constant weight at atmospheric pressure and at a temperature just above the boiling point of water For many biological products such as feeds and the excreted feed residues, such drying results in a loss of volatile fatty acids, and of some sugars that decompose at temperatures above 70°C Such substances will obviously be counted as water

Drying at lower temperatures *in vacuo* helps in some cases but necessitates vacuum ovens Such ovens are usually of relatively small capacity, which may be a problem if much routine work is involved

The direct determination of water is often done by distillation, using toluene as the product immiscible with water The distillate is received in a calibrated sedimentation tube with a side arm that

returns the medium to the distilling flask while the water is trapped in the calibrated tube. An apparatus for a continuous extraction of water and fat from biological materials was designed in the Department of Nutrition, Macdonald College (see Fig. 2-1).

The significance of the water content of feeds depends on the kind of feed and the amount of water. The greatest difference in nutritive value between many feeds, as fed, is traceable to differing moisture content. For example, using Total Digestible Nutrients (TDN) as a measure of overall energy value, the cereal grains and some of the tubers show almost the same feed values per unit of their dry matter content.

Food	% Water	Energy value (TDN) As eaten	Energy value (TDN) Dry matter basis
Corn	10	80	90
Barley	10	77	85
Oat meal	10	70	78
Melons	94	5	80
Potatoes	79	18	85
Sweet potatoes	68	26	82
Sugar beets	87	10	77
Apples	82	13	74

Dry matter, therefore, becomes a common denominator for the comparison of foods, particularly as to energy value. This applies, however, to all other nutrients.

Note that it is customary to report the proximate principles on a moisture-free basis in tables of food composition. Moisture is then given separately for any further information that it alone conveys. This plan is not always followed, and you must be sure in making comparisons between feeds in nutrient content that the figures are expressed on comparable bases insofar as moisture is concerned

The problem of food storage is complicated by high moisture content. Foods carrying more than 14 per cent moisture cannot be stored in bulk. They are likely to mold, and spontaneous combustion may also take place. The problems of moisture content in relation to storage are serious in the case of some grains. Corn grain, for ex-

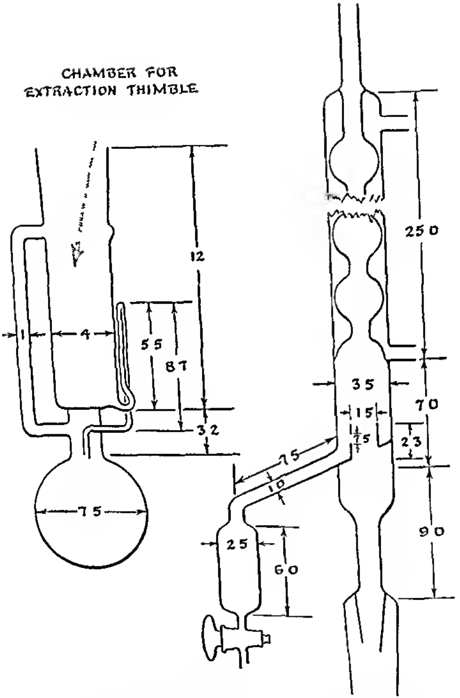


Fig 2-1 *Diagram of apparatus for extraction of fat and water (All measurements are in centimeters)*

ample, is officially graded on the basis of moisture content. The grade of shelled corn, its water content, aod its feeding value as indicated by TDN is shown in the following table:

Grade of shelled corn	Per cent water	TDN
1	12.8	82.5
2	14.8	80.6
3	16.5	79.0
4	18.8	76.8
5	21.5	74.2
Soft	30.5	66.7

Moisture content in newly harvested grains is also likely to be higher than that which will be found in the same feed after several months storage io barns or elevators. Sometimes the change in moisture content is a factor complicatıng the estimate of the quantity of farm grain oo hand. If one takes the initial value as the basis of calculation he is likely to find a shrinkage of at least 5 per cent in moisture during the course of a winter storage and may, consequently, over-estimate the feed available.

The relative cost of food per unit of nutritional value frequently involves the consideration of water, since water is not a nutrient in the usual sense. Thus, sometimes grains or grain by-products are offered for sale at what appear to be bargain prices, but which, on investigation, show that these samples are high in moisture content and that the price per unit of dry matter is no particular bargain after all. This situation arises with such feeds as brewers' grains and distillers' grains, or other products that, in the process of manufacture, have been wet and must be dried by artificial heat. The cost of drying is considerable, and when the material can be sold in a partially dried state it can be reduced in price.

The moisture content of forages that are to be preserved by ensiling is also of some importance, since it affects the ease with which cnsiling can bc effccted. For grass silages the newly cut forage must frequently be wilted to reduce the moisture content to about 70 pcr cent. On thc other hand, more mature forages ofteo require the

addition of water during the ensiling process in order to facilitate the packing needed to exclude air from the mass

One further problem that is related to moisture content is that of dustiness often encountered when excessively dry feeds are ground in preparation for feeding Animals universally dislike dusty feeds, and, consequently, rations prepared from ingredients that are powdery in nature are eaten less readily than others of more granular composition Very dry grain and such products as alfalfa tend to produce an excessively dusty ration, which may be partially relieved by adding small quantities of water, or by steaming, or by feeding the product as a wet or moistened mash Another corrective for dusty feeds is the addition of such a product as molasses, which tends to cause the dusty particles to stick together and destroys their objectionable nature

Quite aside from all we have said above concerning the significance of water in feed, we should not forget that though not counted as a nutrient, water is nevertheless a dietary essential, and its amount in relation to caloric intake is perhaps more critical than with most other nutrients The quantitative requirements for water are discussed in another section, but we want to point out here that the first response of the animal to a restriction of water intake is a restriction of voluntary food intake This may amount to as much as 25 to 30 per cent restriction in food consumption and a similar decline in the efficiency of the feed as measured by the gain made per unit of feed eaten Consequently, the water content of feeds, particularly those that are normally high in water, such as silage, fluid milk, pasture forage, roots, etc , is an important consideration in their feeding value and in the overall requirement of the animal for water Water that is not supplied with food must be supplied from some other source, and some foods owe their chief nutritional properties to their water content

On the other hand, forcing animals to consume too much water may limit their intake of nutrients because of the limited capacity of the digestive system Thus, we find that milk as the entire diet of animals past weaning age is so bulky because of its water content that they are unable to consume as much of other nutrients from the

dry portion of the milk as they would otherwise take, and, consequently, they do not grow as rapidly as other animals not forced to take such a bulky diet. Much the same situation may occur in the slop feeding of pigs if the meal-water mixture is made too thin and of food so fine that it stays in suspension.

Feeding standards do not include the water requirement for animals, and this is perhaps an omission that should be corrected. One reason for the omission is obviously the difficulty of stating the water requirement for specific animals, inasmuch as it differs with the composition of the animal's diet.

In the absence of any better information the approximate water that should be provided as beverage, where it is impossible to furnish water *ad libitum*, may be calculated from the caloric requirement. The digestible calorie intake for any animal is not far from one hundred times the body weight raised to the three-quarter power where body weight is expressed in kilograms [100 ($W^{.75}$)]. The quantity of water to be provided as beverage is, for average conditions, about one millilitre for each three Calories calculated from the above formula, i.e. [33 ($W^{.75}$)]. The balance of the day's water is provided by metabolic water and that which is contained as free-water in the foods eaten.

Ether Extract

In most cereals and animal products used for food the fat or oil obtained by expression is practically the same chemically as that extracted by ether. It consists of

Glycerides of fatty acids	Chlorophyl
Free fatty acids	Alkali substances
Cholesterol	Volatile oils
Lecithin	Resins

The chlorophyls, alkalies, volatile oils and resins are not classed as nutrients but are, nevertheless, found in the ether extract of feeds.

The ether extract will differ in composition among different foods, and it may be quite unlike fat or fatty oil. In particular, ether ex-

tract from different feeds will likely differ in sterol content, and since this has no energy value it will affect the energy value of the product For all practical purposes the food value of ether extract will be more nearly correlated with its content of neutral fat than with any other component, barring possibly a few products such as alfalfa in which the Vitamin A content is of particular importance

Thus we must remember that the food value of ether extract *is* not constant, in spite of the fact that in practice it has been taken as yielding 9 35 Calories of gross energy or approximately 9 Calories per gram of metabolizable energy as consumed in the diet

The useful energy of dietary ether extract is its gross energy minus that found in the subsequent fecal excretion (i e, the loss in digestion) However, when feces are extracted with ether, soaps that may have been formed in the intestinal tract from free fatty acids and calcium will not be removed This incomplete recovery of the fecal fat gives erroneously high values for the digestibility of the ration fat, particularly in practical diets containing relatively high calcium content

Estimates of ether extract in feeds may be made either by weighing the extracted material after evaporating the solvent, or alternately by recording the loss in weight of the moisture-free sample following its extraction by anhydrous ether The second method makes it possible to employ a multiple sample extraction procedure The samples are weighed into Alundum crucibles, oven-dried, re-weighed, placed in groups in the extraction chamber, extracted, and again weighed following extraction of the sample The samples, without transfer from the extraction crucibles, can then be ignited in a muffle furnace for the determination of crude ash This procedure, unless very exact values are necessary, is probably preferable to the extraction of single samples by standard Soxhlet procedures

The fat content will be the major factor in causing differences in the gross energy of various foods and feeds, because carbohydrate materials and protein materials yield somewhere in the neighborhood of 5 Calories per gram, while the ether extract yields a little over 9 Calories

Nutritional Significance of Ether Extract. The nutritional significance of ether extract in the diet is a matter on which there is still some disagreement. To the extent that it is normally the source of the essential fatty acid (linolenic) it is admittedly indispensable. However, an animal requires only a matter of a few grams of ether extract from most feeds to supply all of the necessary linolenic acid. Otherwise, many authorities believe that the only function of this fraction of feeds is as a non-specific source of energy.

Deuel,* however, has reviewed the recent evidence on this question and has arrived at the conclusion that dietary fat *per se* has specific nutritional functions quite unrelated to essential fatty acids and in addition to its function of providing calories in "concentrated" form. There can be little doubt that the addition of fats to many diets or rations lowers the specific dynamic action of such diets and hence results in a greater energy efficiency of a given calorie intake. In other words, the higher efficiency of fat calories appears to be the result of a reduced heat loss on the higher fat diets.

Deuel summarizes his conclusions as follows: "It is as yet a moot question whether the beneficial effects of fats, nutritionwise, are to be ascribed solely to the EFA (essential fatty acids) which they contain, or whether triglyceride fats have a specific nutritive value *per se*. The beneficial effects of high fat diets on pregnancy, lactation, and possibly on growth can probably be largely, if not entirely, ascribed to their EFA content. On the other hand there is no positive evidence that the improved caloric efficiency resulting from the associative dynamic effects, or the sparing action of fats on certain phases of protein metabolism are necessarily functions of EFA. Some of the beneficial effects of fat are undoubtedly to be traced to the establishment of definite enzyme patterns when high fat diets are consumed over an extended period. . . . It may be that increased capacity for work, noted in rats receiving high fat diets, is a reflection of the establishment of such new enzyme patterns."

The lipide content is of importance in the selection and use of feeds. For example, the bulkiness of whole milk is compensated for

* *Proc. Fed. Am. Soc. for Exp. Biol.*, V. 14, p. 639 (1955).

by the high energy of its fat content Without this component, milk would not be useful as the early diet of the mammal Its bulk with relation to the capacity of the digestive tract would make it impossible for the young animals to consume enough energy for their early growth needs

As we shall see later, oilmeals prepared by heat and pressure may contain up to 10% fat, and as a consequence their TDN is sometimes higher than that of basal feeds The effect of more complete removal of the oil, as by solvent extraction, on their available energy yield is indicated in Table 2-1

TABLE 2-1 *Effect of Fat Removal on TDN of Oilmeal Feeds*

Feed	Preparation	% Fat in meal	TDN of meal
Soybean	None	17	86
	Expeller	6	83
	Solvent	1.5	78
Linseed	None	36	109
	Expeller	6	78
	Solvent	3	72
Peanut	Expeller	8	82
	Solvent	1.5	74

It is the fat portion of feeds that is the most unstable This feature makes the storage of high fat feeds a problem Rancid feeds are objectionable, because they have usually lost appreciable quantities of such nutrients as Vitamin A or its mother substance carotene, and may also have suffered oxidative destruction of some of the essential fatty acid In addition the chemical changes may have caused the formation of undesirable substances such as amines Furthermore, the rancidity may proceed to the point of heating and the actual combustion of the feed The greater the degree of unsaturation of the fats present the greater the danger from this damage All plant oils are subject to easy rancidity

These fatty materials as they occur in the seeds of the grains are quite stable, but if the grain is ground the lipases are likely to be

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activated by the heat and moisture of the process and the fatty fractions then quickly become rancid.

Fat-free or even very low fat-containing rations are frequently found to be less acceptable to animals than those of greater fat content. Just where this fat level should be set in this connection is not by any means clear and probably depends, in part, on species of animal as well as age, and perhaps on conditioned preference. In studies at Macdonald College Nutrition Department one of the consequences of the fortification of low-fat rations (less than 2% ether extract) with up to 20% of some 9 different fats and oils was that young pigs weaned at 10 days and puppies weaned at 14 to 21 days learned to eat from self-feeders diets that carried 7% of fat or over more quickly than they did the 2% fat control diets. Young guinea pigs weaned at 2 days of age, however, did not show this preference. As we might expect, once these young animals had learned to eat the diets, the effects of the fat additions were largely traceable to the greater energy value of the mixtures.

The observation that animals accustomed to a corn ration show a dislike for its replacement by barley but not by oats, while the reverse is not true, has led to the general belief that the low fat of barley is the factor responsible. This is no doubt a conditioned preference, for animals that have been raised on barley rations consume voluntarily as much of these rations as do comparable animals raised on corn mixtures.

It may also be worth noting that some feed manufacturers prefer to fortify their ready-to-feed mixtures with Vitamin A through the use of low potency fish oils. The oil thus added is helpful with mixtures that, when ground, are otherwise inclined to be dusty.

The nutritional usefulness of ether extract obviously depends in part on the extent to which it is *digested*, and while neutral fats are normally digested something in excess of 90 per cent, this may not be true with the ether extract from animal feeds. The assumption that of the 9.35 Calories per gram of potential energy found in fats of foods typical of the human diet approximately 9 Calories is available for body metabolism cannot be safely applied in the case of ether extract obtained from feeds typical of animal rationing.

The problem is clearly illustrated in a tabulation of the *coefficients of digestibility* of ether extract for a few animal feeds (see Table 2-2)

TABLE 2-2 *Coefficients of Digestibility of the Ether Extract of Certain Feedstuffs*

Feedstuff	% Ether extract	Coefficient of digestibility by cattle %	Coefficient of digestibility by swine %
Alfalfa	1.8	36	14
Barley (grain)	1.5	60	44
Brewers grains	7.3	89	60
Corn (grain)	4.0	87	46
Cottonseed meal	10.2	92	90
Fish meal	7.4	97	81
Hominy feeds	7.7	96	—
Linseed oilmeal	6.3	89	62
Milk	4.6	100	97
Oats (grain)	3.5	82	82
Soybean oilmeal			
(expeller)	6.0	84	—
(solvent)	1.2	38	58
Tankage 12% fat	11.9	100	96
2% fat	2.0	—	73
Wheat	1.8	—	80
Wheat bran	5.0	62	58

There are several factors that affect the digestibility figures of ether extract the first of which is the fact that we are dealing with apparent digestibility rather than the true digestibility By definition the apparent digestibility of a nutrient is the percentage of the intake that is not recoverable in the feces With ether extract the problem is complicated by the fact that some ether extractable material is synthesized in the digestive tract presumably by microorganisms, and, consequently, appears in the feces It is designated metabolic fecal

fat Obviously anything that increases the fecal fat is reflected in a lowering of the apparent digestibility coefficient for that nutrient This proportion of fecal fat may be an appreciable value, particularly in the case of low fat intakes To the extent that metabolic fecal fat is of bacterial origin and perhaps synthesized initially from dietary carbohydrate rather than dietary fat, there is an error in the usual assumptions concerning the significance of digestible ether extract (Low fat diets often give negative digestibility because of metabolic fat)

A second factor influencing the apparent digestibility of ether extract is the proportion of neutral fat in the ether extract consumed This is highly variable between different feeds, particularly if the feeds are roughages, where the neutral fat component of the ether extract may be relatively small Most of the other ether extractives are non digestible, and, consequently, the apparent digestibility of ether extract becomes a low value

Schneider has examined the digestibility coefficients of something over twenty thousand digestion trials and from his data has determined partial regression coefficients that can be used to predict the coefficient of digestibility for ether extract of feeds where the proximate analysis of that feed is known He has also prepared partial regression coefficients that can be used in the absence of other data for predicting probable digestibility of ether extract

The equation for calculating the probable coefficient of digestibility of ether extract of a specific sample of a concentrate feed where the average digestion coefficient is known and the proximate composition of the feed is also known, is as follows

$$Y = \bar{Y} - 1\,399\ (x_2 - \bar{x}_2) + 1\,706\ (x_3 - \bar{x}_3) + 17\,317\ (x_4 - \bar{x}_4)$$

In this formula Y is the apparent digestibility of ether extract and $\bar{Y}$ is the average digestion coefficient for fat of the feed in question as given in some table of feed composition and digestibility The values $\bar{x}_2$, x_3, and $\bar{x}_4$ are the percentages of crude fiber, nitrogen-free extract, and fat respectively, also taken from a table of food composition for the feed in question The values x_2, x_3, and x_4 are the corresponding percentages of crude fiber, nitrogen-free extract, and ether extract

from the analysis of the particular sample that is being investigated The numerical values in this equation are the partial regression coefficients applicable to the three proximate principles with which we are dealing

As an example of how this formula works let us calculate the probable percentage digestibility of the ether extract of a sample of barley showing the following composition crude fiber 15%, nitrogen free extract 64%, ether extract 3% The average digestibility of the fat of barley grain fed as the sole ration to swine, taken from Schneider's *Feeds of the World,** is 44% and the average crude fiber, nitrogen free extract, and ether extract figures are 10 7%, 66 6%, and 1 9%, respectively Solution of the equation is as follows

$$Y = 44 - 1\,399\ (15\,0 - 10\,7) + 1\,706\ (65\,0 - 66\,6) + 17\,317\ (3\,0 - 1\,9)$$

$$Y = 54\%$$

This example illustrates how the proximate analysis affects the apparent digestibility of ether extract In this particular example differences in ether extract in the sample in question as compared to the average for all feeds of that class are particularly important in affecting the apparent digestibility of the ether extract

No small portion of this change in apparent digestibility of ether extract is traceable to the indirect effect of metabolic fecal fat, which presumably is a constant Consequently, as the percentage of fat inherent in the feed increases the relative effect of the metabolic fecal fat becomes smaller, and the apparent digestibility, therefore, increases Students of digestibility have failed to stress this effect of metabolic fecal fat on the apparent digestibility and, hence, on the presumed available portion of the dietary fat, and only recently has it become recognized as an important consideration in the calculation of the available energy of a feedstuff

We now realize that the use of a figure such as 9 Calories per gram of useful energy from dietary fat in animal feedstuffs is likely to be quite highly erroneous Even with feeds in which the ether

* *Feeds of the World* Jarrett Printing Co Charleston W Va (1947)

extract is largely neutral fat, the apparent digestibility is oftentimes much below the assumed 90% or more on which the human dietary fat energy has been calculated. Incidentally, this error creeps into the total digestible nutrient values when these are converted by any constant figure to approximate caloric values. Certainly the value of 4 Calories per gram as the energy equivalent of Total Digestible Nutrients is open to much question in this connection.

The significance of the ether extract value for feedstuffs is, therefore, highly variable and were it not for the fact that most feedstuffs are relatively low in ether extract, the problem of the evaluation of feeding value would be much more uncertain than it is.

Schneider has also developed from his extensive data regression equations that make it possible to predict probable digestibility of ether extract of feedstuffs for which there are no basic digestibility data available, provided we can determine the proper category in the feed classification for the product under question. Let us suppose, for example, that we have a sample of very light weight immature frosted barley. Let us suppose that no feeding or digestion trials have been done with this product, and all we have in the way of chemical description is the proximate analysis. The equation proposed by Schneider for dealing with this case in order to get an estimate of the probable digestibility of ether extract is shown as follows:

$$Y = C + b_2X_2 + b_3X_3 + b_4X_4$$

We may assume that our sample analyzes: crude fiber 15%, nitrogen-free extract 40%, ether extract 2%.

The equation with the numerical figures inserted is as follows:

$$Y = -162.9 + 3.240\ (15.0) + 1.946\ (40.0) + 16.204\ (2.0)$$

$$Y = -1.9$$

Here is a case where there is a slightly negative value for the probable apparent digestibility of ether extract. We find this situation occasionally, and again it is a reflection of the effect of metabolic fecal fat. One would assume in this feed that the high crude fiber had probably depressed the true digestibility of the dietary ether extract and, consequently, most of the intake was recovered in the

feces, to which has been added the metabolic fecal fat, so that the sum total recovered is greater than the intake, and we, therefore, obtain an apparent digestibility that is negative

The question of what to do with negative coefficients of digestibility of ether extract is one on which there is no agreement among present investigators If the metabolic fecal fat were synthesized by microflora from dietary fat, the problem would be somewhat simpler It seems probable that the metabolic fecal fat is synthesized from carbohydrate more than from fat, and, consequently, no accurate correction seems possible, and perhaps the common solution of assuming that the digestibility coefficient should be zero is the most satisfactory and practical one, especially for livestock feeds where the amount of fat in the diet is low to begin with.

Crude Fiber

Unless otherwise specified, crude fiber refers to the residue of a feed that is insoluble after successive boiling with dilute alkali and dilute acid in accordance with the procedures originally proposed by the Weende Experiment Station and officially recorded in the procedures of the Association of Agricultural Chemists The question of the definition of crude fiber is of some importance because of the many procedures that have been proposed as improvements in the original Weende Crude Fiber Method These modifications give values for crude fiber that differ from those of the Weende procedure The chief difference is usually that the residues contain more of the lignin, and hence the total values are larger than in the original method

The biological and hence nutritional significance of the crude fiber figure is far from clear and certainly is not precise Crude fiber is the portion of the total carbohydrate of a food that is resistant to the acid and alkali treatment mentioned above, and the original supposition was that it therefore represented an indigestible portion of the feed We have since learned that the Weende crude fiber may be a misleading index of the overall digestibility of a feed, for the simple reason that in an appreciable number of cases the crude fiber

itself is as highly if not more highly digested than the soluble carbohydrate usually referred to as Nitrogen-free Extract

The following data calculated from Morrison's tables of feed composition* and digestibility illustrate this situation

Class of feed	Total cases recorded	% of cases where the fiber is digested by ruminants as completely as is nitrogen-free extract
Dry roughages	111	39
Green roughages	61	20
Silages	25	28
Concentrates	90	10
Weighted average	287	25

The reason for the relatively high digestibility of crude fiber by ruminant animals lies in the fact that the largest component (perhaps 95%) of crude fiber is cellulose, and we know that the microorganisms of the rumen are able to break down cellulose for their own needed energy, and that in the process they produce acetic acid (and some butyric and propionic), which is absorbed from the rumen and supplies energy to the host What many do not realize so fully is that much the same situation holds true with species other than the ruminants

It may surprise some to note the extent to which crude fiber is digested by a variety of species The rations would be those typical of the species cited, and thus the levels of crude fiber in them will not be the same for all species The data do not mean that unlimited quantities of fiber can be digested to the extent shown, nor that there is no optimum level of ration fiber for any given species

We can see from the above data that the digestion of cellulose, and hence of crude fiber, is often of sufficient magnitude to necessitate its consideration in estimating the energy value of foods in the diet

Another reason for considering crude fiber is because it is correlated with the bulkiness of a feed, especially when the feed is ground As we shall see later, bulkiness of ration is an index of available

* *Feeds and Feeding* (20th Ed), The Morrison Publishing Co , Ithaca, N Y

Species	Where digested	% of contained crude fiber digested
Ruminants	rumen	50 90%
Horse	caecum	13-40%
Pig	caecum	3 25%
Rabbit	caecum	65-78%
Rat	caecum	34-46%
Dog	caecum	10 30%
Man	small and large intestine	25 62%
Poultry	caecum	20 30%

energy value, and hence of feeding value Bulkiness is one index that the feeder himself can use for predicting the relative feeding values of certain feed mixtures

The physical role of crude fiber in a ration cannot be overlooked The indigestible residue of feeds of plant origin is largely crude fiber Thus it is material of this nature that gives to rations their physiologically effective bulk The normal peristaltic movements of the intestinal tract are dependent, in part, on internal distention, which is furnished by food residues that have not been attacked by the digestive agents or that, though attacked, have not yielded absorbable fractions

Some such residues are hydrophylic and by their water holding capacity help maintain a moist soft condition of the fecal mass, and thus facilitate its easy passage through the large bowel In particular, hemicellulose residues appear to be hydrophylic and probably owe some of their laxative properties in mono gastric species to this characteristic

In other cases the crude fiber residue" appears to be attacked by microflora with a resulting formation of gas, some of which is not absorbed The result is an increase in fecal mass due to entrapped gas This extra bulk may stimulate peristalsis The bacterial action also results in the formation of free fatty acids and it has been suggested that in the mono gastrics these fatty acids in the large bowel are irritants that stimulate peristalsis

Probably the fiber of some foods is of such a nature that it is physically irritating to the point of being objectionable or even

actively harmful. Thus the diarrhea that they may cause initially may be followed by constipation from excessive bowel constriction, as in spastic colonic conditions.

Herbivora are largely unaffected by the physical nature of the ration crude fiber, perhaps because the organisms that attack it normally produce absorbable fatty acids in the one case, and the provision, through belching, of a means of voiding gases, which in other species must pass through the large bowel with the fecal mass. Bulk of ration with the herbivora is of more importance as an index of available energy value than because of possible laxative properties.

Nitrogen-Free Extract

In order to understand clearly the nature and makeup of the fraction of a feed designated as nitrogen-free extract, we should first consider total carbohydrate. Carbohydrates are a group of substances formed by photosynthesis in the plant and containing carbon, hydrogen, and oxygen with the last two in the proportions of water. Carbohydrates are the chief sources of potential energy of livestock rations, but the different members of the group differ in their yield of *useful* energy because of differences in their digestibility, and to a lesser degree, to the end product they yield on breakdown in the digestive tract.

The carbohydrates of foods can be listed as follows:

- Monosaccharides
  - Dioses
  - Trioses
  - Tetroses
    - Arabinose
    - Xylose
    - Ribose
    - Rhamnose
    - Fucose
  - Hexoses
    - Glucose
    - Mannose
    - Galactose
    - Fructose
    - Sorbose
- Disaccharides
  - Sucrose
  - Maltose
  - Trehalose
  - Lactose
- Trisaccharides
  - Raffinose

Polysaccharides
- Starch
- Dextrin
- Glycogen
- Mannan
- Araban
- Xylan
- Cellulose

Within this family of carbohydrates there are a few which may have some specific nutritional function other than as sources of energy. For the most part, however, the sugars (i e, Mono-, Di-, and Tri-saccharides) and the "starches" (starch, dextrin, glycogen), on digestion, eventually yield blood sugar (glucose), and accordingly are often classed together as one "functional" group. The polysaccharides also include xylan, araban and mannan which are sometimes classed as hemicelluloses. Hemicelluloses, together with cellulose, are found as principal parts of the plant cell wall structure. Lignin, though not itself a carbohydrate, forms a physical combination with cellulose often referred to as lignocellulose, and thus is considered in nutrition with the true carbohydrates. Foods of plant origin usually contain a combination of most of these four kinds of carbohydrates.

The above classification of carbohydrates, based on chemical structure, is not as useful in applied nutrition as is one that groups

CHART 2-A *Functional Grouping of the Carbohydrate of Feeds*

Group	Principal Useful End Product of Digestion	Important Nutritional Functions
Sugars and Starches	Sugar	1) Non-specific and highly digestible source of energy via pyruvic acid
Hemicellulose	Acetic Acid	1) Non specific energy via acetyl phosphate 2) Stimulant to intestinal peristalsis (hence laxative to monogastrics)
Cellulose	Acetic Acid	1) Non specific energy via acetyl phosphate 2) Chief component of ration bulk 3) Source of energy for cellulose-feeding microflora of digestive tract
Lignin	None	1) Inhibits microbial "digestion" of cellulose, hence costive

them on a "functional" basis Such a grouping is indicated in Chart 2-A

The Weende scheme of proximate analysis separates these four functional groups of carbohydrates into two categories crude fiber and nitrogen-free extract The makeup of these two fractions will be apparent from Chart 2-B, which gives the effects of the crude fiber procedure on a dry, fat-free feed sample

CHART 2B *Effects of the Weende Crude Fiber Procedure on Fat-Free Food*

Constituent	Bo ling with 1 25% H_2SO_4	Subsequent bo ling with 1 35% NaOH
Prote n	partial extraction	complete extraction
Starches and sugars	hydrolysis and extraction	—
Cellulose	slight	sl ght
Hem cellulose	variable extraction	extensive but variable extract on
Lign n	slight	extens ve but highly variable extract on

In this chart note that the sample contains protein, starches plus sugars, cellulose, hemicellulose, and lignin (The ash may be disregarded here) We shall consider that the last four items constitute the total carbohydrate Also, since all of the protein is 'dissolved' by the acid-alkali treatments, it, too, may be disregarded for the present It will be evident that any insoluble material remaining after the boiling will be carbohydrate, and will be made up of (1) all of the original cellulose, (2) variable proportions of the hemicellulose, and (3) a small, though again highly variable, proportion of the lignin These three together constitute *crude fiber*

Indirectly (that is "by difference") we see that nitrogen-free extract is a mixture of all of the starches and sugars of the sample, plus some hemicell ose, and much of the lignin In actual fact nitrogen-free extrac is the difference between the original weight of the sample and ie sum of weights of its water, ether extract, crude protein, cruc fiber, and ash, as determined by their appropriate analyses Thus ts numerical value will be affected by the chem-

ical errors in the analyses of all five of the separate fractions, as well as by the lack of precision of the crude fiber procedure in accurately separating the functional categories of the carbohydrates

Nevertheless, nitrogen free extract is a practically useful index of the non-cellulose portion of feed carbohydrates, and is primarily a non-specific source of energy to the animal Its digestibility is variable, though ordinarily a little higher than that of the protein, fat, or crude fiber of the same feed Some idea of the differences in digestibility of these proximate fractions, as well as of their variability between feeds is indicated by data taken from Morrison's* tables of feed composition

TABLE 2-3 *Digestibility of Protein, Fat, Fiber, and Nitrogen Free Extract of Typical Roughages and Grains*

Feedstuff	Protein	Fat	Fiber	Nitrogen free extract
	%	%	%	%
Alfalfa	72	33	41	71
Clover	59	58	51	69
Timothy	46	48	51	58
Mixed Hays	50	47	61	62
Average	57	47	50	65
Barley	79	80	56	92
Corn	76	91	57	94
Oats	78	88	38	81
Wheat	86	83	90	95
Average	80	86	60	91

On the basis of these figures one might estimate that nitrogen free extract from dry roughages will yield to an animal about 3 Cals , and from dry concentrate feeds about 4 Cals per gram of digestible (and also of metabolizable) energy

The importance of nitrogen free extract as a source of energy to the animal lies in the fact that this fraction makes up about 40%

* *Feeds and Feeding*

of the dry weight of roughage feeds; and 70% in the case of the basal feeds. In general, the proportion of nitrogen-free extract in concentrate feeds will be inversely related to the protein content, so that protein supplements may have as little nitrogen-free extract as the roughages.

Crude Protein

Crude protein is the figure usually obtained by multiplying the nitrogen of the feed by the factor 6.25. In some cases crude protein is now determined by multiplying the nitrogen by some other factor, depending on the percentage of nitrogen that is known to be in the protein of that particular feed. Such special figures are commonly employed for wheat and for milk products, but unless otherwise specified we should assume that the protein content given in a table of feed analysis represents nitrogen times 6.25.

From the amount of publicity that has been given to protein content in feeds and in rations, it is not surprising that in the feeder's mind protein frequently looms up as the most important component of a feedstuff or of a ration. Nothing could be further from the truth. In fact, altogether too much relative importance has been given to protein in practical feeding operations.

We should not assume, however, that protein is not an important consideration in feeds; actually it is important for several reasons. In the first place, we may note that the usually accepted classification of feedstuffs is essentially one based on protein content. Basal feeds are low protein feeds. Protein concentrates are high protein feeds. Legume roughages are higher in protein than non-legume roughages, and both these are higher in protein than straw. Therefore, by knowing the protein content of a feed we can get some idea of the class of feed to which it must belong, even though we do not know its other characteristics.

Probably also the protein content of a feed is an indirect measure of its total digestible nutrients, because the protein component of feeds is usually highly digested as compared, for example, to the coarser carbohydrates. Consequently, in roughages that are high

in protein, we are almost sure to be dealing with roughage that is correspondingly lower in crude fiber Therefore such a product is more digestible than one that has a high fiber content and a lower protein content To a limited extent this same situation holds true with the concentrate feeds

The over-emphasis on protein has largely been in connection with what has been believed to be the minimum necessary in satisfactory rations for livestock Before our knowledge of the great variety of nutrients required by animals was anything like as complete as it is now, practical experience frequently was such as to lead the feeder to believe that additions of protein supplements to his grains, or to some mixture that he was previously feeding, gave improved results because of the increased protein in the diet Now we know that when proteins are added to feeds in the form of high protein feed-stuffs, that in addition to protein many other factors are also added to the ration We can understand why this is so when we realize that most high protein feeds are high in this nutrient merely because either starch or oil has been removed from the original product Consequently, not only protein but all of the other nutrients in the feed except starch (or oil) are concentrated as compared to their levels in the original product The fact that animals use surplus protein in the ration quite acceptably as a source of energy has often been forgotten Tests, however, have indicated that when the addition of extra protein in the form of a protein supplement has given beneficial effects in feeding practice, that very often additions of sugar to the same ration has given equally good results, thus indicating that the supplementary feeding has been beneficial because of added energy rather than because of added protein The tendency today is to reduce the figures believed to represent protein requirements in view of our greater knowledge of the nutrients that are actually needed to make a ration more acceptable

Protein serves both as a source of energy and as an index of the total of the amino acids of the feed We must recognize the limitations of this figure in both respects As a source of energy protein is subject to a loss of about 20% This is a consequence of

the failure of the body to "burn" the urea formed from deaminized amino acids When this loss is added to that from incomplete digestion we find that only about 60% of the potential energy of a feed protein becomes available to the animal to meet caloric needs Thus it is evident that when the ration is to be enhanced as to energy, protein is not the preferred source

As a measure of the total of the amino acid complex we must recognize that not all proteins contain 16% of nitrogen, and hence this estimation from the nitrogen determination and the conventional factor 6 25 leads to inaccuracies of varying degrees

The nitrogen content of different feeds ranges from 13% to 18% (see Table 2-4) In general, the proteins of the oil seeds show the

TABLE 2-4 *Protein Content of Selected Foods* (Showing errors of estimate resulting from use of a constant factor 6 25)*

Food	% N in protein	% N in feed	Calculated N × 6 25	Specific factor	N × factor
Wheat endosperm	17 5	1 39	8 7	5 70	7 9
bran	15 8	2 45	15 3	6 31	15 5
entire	17 2	2 06	12 9	5 83	12 0
Barley	17 2	1 68	10.5	5 83	9 8
Corn	16 0	1.54	9 6	6 25	9 6
Cottonseed oilmeal	18 9	5 82	36.4	5 30	30 8
Flaxseed oilmeal	18 9	5 82	36.4	5 30	30 8
Peanut	18 3	4 13	25 8	5 46	22.5
Milk	15 8	0 53	3 3	6 38	3 4
Eggs meat	16 0			6.25	
Gelatin	18 0	1 46	91 4	5.55	81 2

* Jones D B U S D.A Circular 183 (1931)

most marked discrepancies from the figure of 16% On the average the nitrogen figures and the corresponding conversion factors to protein for feeds might be taken as

Origin	% N in protein	Conversion factor
Oil seed proteins	18 5	5 4
Cereal proteins	17 0	5 9
Plant leaf	15 0	6 6
Animal or fish	16 0	6 25

The solution for greater accuracy, however, is not entirely straightforward In many cases it is an estimate of the apparent digestible protein that is needed to assess feeding value, and by definition this is the portion of the protein intake not recovered in the feces But a part, and often a large part, of fecal nitrogen is of metabolic origin, to which the conversion factor for the feed protein may not apply Consequently, the more appropriate factor for the feed nitrogen may, if applied to the fecal nitrogen, compound the final error in the estimate of the digestible protein The practical aspects of the problem may be of less importance than we might think at first Feeding standards and feeding experience have established with usable accuracy the protein levels needed in rations for various feeding situations, and the development of feeding standards for individual amino acids now makes it possible, where necessary, for the feeder to make a more accurate adjustment of protein intake based on its quality than he could hope to do from any estimate made from nitrogen figures alone

Thus while N × 6 25 may be a somewhat rough estimate of total protein and little or no estimate of its quality, it still is a reasonably satisfactory index on which to express the need for protein and by which to compound practical livestock rations with respect to this nutrient Quality of protein is of relatively minor importance in the rations of herbivorous animals, and with other farm stock the presence of adequate essential amino acids can be reasonably well assured by the inclusion in the rations of small quantities of feeds of animal or marine origin, with the possible exception of rations for very young animals

Ash

This is the inorganic residue from the firing of a sample at about 500°C The nutritional significance of the ash figure will depend, in part, on the food under consideration

Crude ash may enable a calculation of calcium and/or of phosphorus from certain products such as bone meal, or, indeed, of feeds of animal or marine origin with sufficient accuracy for practical use since the make-up of such ash is relatively constant For plant materials, however, the figure for crude ash has little direct nutritional use excepting as it is necessary for the calculation of carbohydrate or of nitrogen-free extract by difference, or occasionally where we want the figure for total organic matter The reason that the ash from plant materials is a poor index of any of the inorganic nutrients is because the ash component of plant materials is highly variable, not only in total amount but in its component parts Many foods are high in silica, an element that is of no nutritional value (although it may be a liability in such materials as the hull of coarse grains), but which, nevertheless, may be a factor in the total crude ash reported in the sample

We should also note that with some types of food the ash figure may be much magnified because of adhering sand or mineral material of that nature, as, for example, in pasture forage where soil has been splashed onto the forage

Another Look at the Proximate Analysis

The student of feeds, after careful and detailed scrutiny of the faults and limitations of the proximate principles of the so-called 'standard feed analysis,' is sometimes left with a feeling that the whole scheme is a delusion as a useful description of the nutrient properties of feeds, and that it might better be abandoned In order to re-establish perspective therefore, we should at this point look again at this method of feed examination

In brooding over the fact that values for crude protein, crude fiber,

ether extract, etc lack the precision which a chemist would demand in the analysis of a single technical entity, we have a tendency to forget the equally important fact that these feed fractions are not chemical entities but mixtures of substances that cannot be uniquely characterized chemically The surprising thing is that any scheme of chemical description of the overall nature of a feed can succeed in giving as practically useful a picture as does this Weende method For example, this analysis establishes unerringly the category in which a feed belongs It is an adequate guide to its fatty and/or watery nature and hence to its stability in storage Proper interpretation of the figures for the carbohydrate fractions gives adequate information as to the class of animal for which it will be most suitable And as a basis for determining the useful digestible or metabolizable energy of a feed the proximate analysis has been the cornerstone Indeed, the feed industry has been built on it, and our modern knowledge of nutrition has been supplementary to rather than a replacement for it

Our difficulty lies first in demanding something from the analysis that with our expanding knowledge of nutrition we think is desirable, but which this scheme was never intended to give, and secondly in our failure, because of uncritical or perhaps erroneous thinking and deduction to properly interpret the figures this analysis yields

The Weende analysis does not define the nutrient content of feeds It is an index of *nutritive value* only because the fractions that it isolates are correlated with some of the properties of feeds that have nutritional significance Consequently, it is a useful descriptive device in establishing the characteristics of feeds As with any other specialized tool to use it correctly and to its full potential requires much other nutritional knowledge and judgment An appreciation of its design weaknesses and limitations, though often stressed in destructive criticism is more correctly assessed as an aid in making the full legitimate use of a scheme of feed description, which has broad and basic value

PROBLEMS

1 Using a well-known feed such as corn, soybean oilmeal, or wheat bran, prepare a table listing for each of the nutrients indicated in Chart 1-A, the quantity present in the feed In a parallel column list the quantities of each of the proximate principles contained in the same feed in such a way that the nutrients included in each proximate fraction are shown How much useful information on the nutrient makeup of the feed is (1) masked by the Weende analysis scheme, (2) is omitted entirely by this analysis?

2 Using the combination of feeds shown as "recommended" in the flexible formula for a 15% protein swine ration (Chapter 19, page 377) calculate from the average DCP and TDN of these feeds the DCP and TDN of the mixture Then, using for these feeds their proximate analysis, and Schneider's regression equations compute the digestibility of the protein, fat, fiber and nitrogen free extract of these feeds You now have data from which to compute the DCP and TDN of the ration mixture How closely do your figures obtained by the two methods agree?

3 In the 1953 N R C Swine Standard are given examples of meal mixtures for 100 lb pigs Ration No 1 contains 63% corn while No 3 is 83% barley Calculate for these two mixtures the % crude fiber How much difference in the TDN of each of these rations would the following assumptions make, (1) that none of the fiber is digestible (2) that 25% of it is digestible?

4 From Schneider s *Feeds of the World*, Table 3, prepare a list of the different coefficients of digestibility of crude fiber for corn, barley and oats which have been reported from feeding tests with swine Compare these in each case with the corresponding TDN figure What explanation can you offer for these figures Do you think an average coefficient of digestibility should be regarded as a "constant" for a given feedstuff?

SUGGESTED READING

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CHAPTER 3

Schemes of Describing the Energy Value of Feeds

Total Digestible Nutrients

WITH OUR increased knowledge of the needs of the body, the inadequacy of the relatively simple scheme of proximate analysis has become more and more apparent. Not only are some of the substances within the several groups of widely different biological significance, but the scheme omits much essential information concerning the nutritional properties of foods.

We shall note, however, that it is from the proximate analysis that the figures for Total Digestible Nutrients are calculated.

From the standpoint of the nutritionist it is often true that the most useful purpose served by the proximate analysis is as a basis for estimating the overall available energy of a feed. The information we can get from the protein figure as such is, of course, important, but not in as exact a sense as was at one time believed. All of the fractions of the dry matter of a feed separated by the Weende analysis, excepting ash, are potential sources of energy; the carbohydrate, protein and ether extract yielding approximately 4.3, 5.6, and 9.3 Calories gross energy per gram. If only approximate values are needed the gross energy of a feed may thus be calculated from its proximate analysis.

The animal, however, is not able to obtain all of the potential

energy from the food it eats The chief, and also the most variable factor between feeds limiting utilization, is failure of complete digestion In this function the different energy yielding proximate principles release in individual cases from 10 to 95% of their gross energy as measured by the quantities of protein, fat and carbohydrate recoverable from the appropriate fecal excretion of the ration consumed We shall deal with the limitations of this method of measuring the apparent digestibility of these nutrients at a later point Here we refer to the matter only in connection with a consideration of a part of the presently used method of arriving at the value termed Total Digestible Nutrients (TDN)

The thinking behind the use of TDN is entirely straightforward If we add together the digestible portions of the crude fiber, nitrogen-free extract, the protein, and the ether extract of a feed, each weighted in accordance with its appropriate caloric value, we can get a figure representing the total digested energy expressed in terms of calories for that feed Assuming a feed analyzing 10% protein, 3% ether extract, 10% fiber, 65% nitrogen free extract, 2% ash, and 10% water, we might calculate the caloric yield as follows

TABLE 3-1 *Calculation of Calorie Yield of a Feed from Its Proximate Analysis*

Proximate principle	% Content	Average Caloric values per gram	Gross Calories	Average % digestibility of fraction	Digestible Calories
Protein	10	5 6	56 0	75	42 0
Ether extract	3	9.3	27 9	90	25 1
Fiber	10	4 3	43 0	50	21.5
N free extract	65	4 3	279.5	90	251 6
Ash	2				
Water	10				
Total (gms)	100		406 4		340 2
Per gram			4 1		3 4
% Digestible energy (as calories)					83%

In this example we find that the hypothetical feed carried a potential or gross energy content of 4.1 Cals. per gram. When the apparent digestibility of each energy yielding fraction is considered, the amount of energy apparently absorbed into the body following its digestion becomes 3.4 Cals. or 83% of the gross energy. Essentially, we would get this result by direct measurement by using a bomb calorimeter and measuring directly the calorie value of the feed and of the subsequent appropriate feces voided. Neither the values of 3.4 Cals. per gram nor the figure of 83% digested energy are the TDN values that we would obtain by the actual procedure used in arriving at the TDN.

By definition the TDN in 100 units of feed is calculated as:

$$\text{TDN} = \text{Dig. Protein} + \text{Dig. N-free Extract} + \text{Dig. Fiber} + (2.25 \times \text{Dig. Ether Ext.})$$

Using our example we would find:

$$\%\ \text{TDN} = (10 \times .75) + (65 \times .90) + (10 \times .50) + (3 \times .90 \times 2.25) = 78\%$$

The discrepancy between the two calculations arises from several sources, appreciation of which should make clear some of the limitations of TDN as a term descriptive of the useful energy of a feed.

The method of calculating TDN appears to come from a combination of the digestible nutrient figures for animal feeds and the Atwater* scheme of arriving at the metabolizable calories yielded from foods in human nutrition. The metabolizable calories from dietary protein are less than the digestible calories because of the potential energy of the urea excreted via the urine. Atwater found this loss amounted to 1.25 Cals. per gram of digested protein. This results in a metabolizable energy value for food protein of

$$(5.65 \times .92) - 1.25 = 4 \text{ Cals. per gram.}$$

Again, in the case of the human, if we compare the digested calories from one gram of fat of the diet to that of the digested

* See Maynard, L. A., *J. Nut.*, V. 28, p. 443 (1944); also *J. Nut.*, V. 31 (1953).

carbohydrate and/or to the digested protein less its appropriate urinary loss, the ratios are about 9 to 4, or 2 25 to one Since the apparent digestibility of fat and of carbohydrate are about the same (in the human diet), the ratios of their gross energy is also about 2 25 to one $(9\ 3 - 4\ 1 = 2\ 26)$ Hence, metabolizable fat can be expressed as its "carbohydrate equivalent" by multiplying by 2 25 Having thus expressed the fat, protein and carbohydrate in equicaloric values of 4 Cals per gram, we can add them to give a "total metabolizable energy" in terms of weight rather than calories

The use of such a method with farm animal feeding appears to date back to 1900 when Hills of the Vermont State Agricultural Station suggested that the fat (ether extract) and the carbohydrate be combined in cattle feeding standards into one quantity by multiplying the fat by 2 25, a figure obtained from the ratio of the gross caloric values of 9 3 for fat and 4 1 for carbohydrate Some ten years later the Vermont workers (Hills et al, 1910) and Woll and Humphrey of the Wisconsin Station, added digestible protein to the digestible fat-carbohydrate "carbohydrate equivalent" and coined the term *Total Digestible Nutrients*

The literature gives no further explanation of this term, but we may assume that it was intended to apply only to digested nutrients If this is true, then the caloric value of the protein should be its heat of combustion minus only its fecal loss In the Atwater scheme the average apparent digestibility of protein is taken as 92%, and the digested energy per gram from protein would correspondingly be calculated as $5\ 65 \times 92\% = 5\ 2$ Cals However, the digestibility of the protein of animal rations is considerably lower than 92%, approaching more nearly 75% for the grains constituting the entire ration and 85% for protein supplements as measured indirectly If some constant value for digestibility must be assumed for the protein of rations as fed, 80% might be used for those not including roughage, or 60% for rations including the normal roughage component for cattle For rations without roughage then we could estimate the digested energy from protein to be $(5\ 65 \times\ 80) = 4\ 5$ Cals or for rations with roughage $(5\ 65 \times\ 60) = 3\ 4$ Cals per gram In neither case is the value equal to 4 Cals per gram

Furthermore, one might question the 4 Cals. per gram for carbohydrate, since its mean digestion coefficient for feeds with appreciable quantities of crude fiber will be lower than the 98% found by Atwater for the carbohydrate of human diets. A digestibility value of 80-90% for nitrogen-free extract and of 50-75% for crude fiber would be more in line with the experimental data, though the values for crude fiber will be highly variable between feeds and between species of animals.

In spite of these facts, the custom has long been followed of considering 4 Cals. as the digestible *caloric value of a gram of TDN.* It obviously assumes that both the digestible protein and fat have, by the method of calculation, been acceptably expressed on a digestible carbohydrate equivalent basis, an assumption that may be questioned. The correct values in our example would be $(453.6 \times 3.4) = 1542$ Cals. per pound TDN which is some 15% lower than the customary factor of 1814 Cals.

The caloric value of TDN of individual feeds will differ according to their proximate composition. An average for all feeds appears to be in the neighborhood of 4.4 Cals. per gram or about 1990 Cals. per pound TDN. Such a factor would need to be used with discretion, however, in the case of individual feeds.

For example, the apparent digestibility of each of the energy yielding fractions is based on the assumption that all of each fraction that is not recovered in the feces has been absorbed and hence potentially available to the animal. Aside from the problems of metabolic fecal products, there is another that is completely disregarded in the TDN calculations; namely, the energy lost as belched or otherwise voided gas, resulting from carbohydrate fermentation in the digestive system. In the case of the ruminant this can amount to 20% of the gross energy of the crude fiber fraction of the ration. Thus TDN values for roughages consistently and appreciably overestimate the usable energy of such feeds by ruminant animals.

The practical problem of the use of TDN as presently calculated is not as serious as we might at first assume; because the values for feeds and those appearing in the feeding standards are all based on the same method of calculation, and hence give a consistent result.

But when we make comparisons between TDN and other methods of expressing the digestible caloric value of feeds, or of compounding rations from the TDN value of feeds to meet standards expressed in terms of calories, we experience difficulty

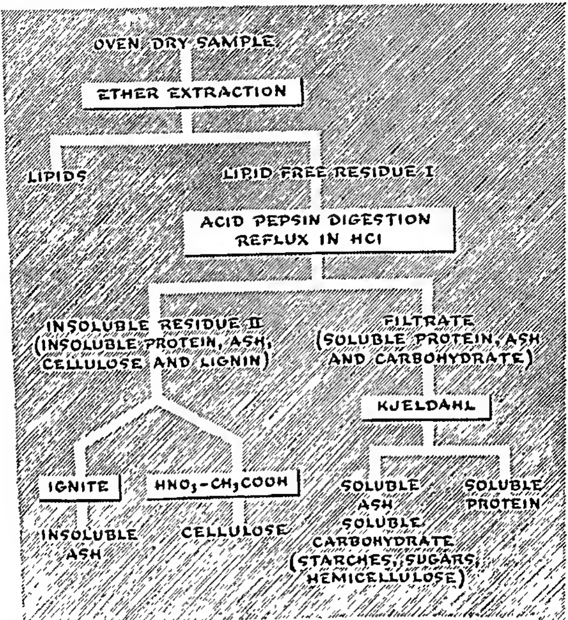
Modifications of TDN Scheme. We should not assume that the proximate analysis according to the Weende scheme is the only one of its type that is applied in dealing with groups of nutrients or with estimates of the nutritional properties of foods For example, there have been several proposals for dealing with the carbohydrate fraction, all of which have the object of avoiding the empirical determination for crude fiber as well as of obtaining a fraction that is more nearly a biological unit

Crampton-Maynard Plan.* This plan calls for the chemical isolation of cellulose and of lignin, the rest of the carbohydrate is then determined by difference and called "other carbohydrate " The chief theoretical objection to this method at the moment lies in the fact that no entirely satisfactory chemical method is available for the determination of lignin Indeed, many now believe that lignin is not a substance of fixed chemical structure but that it may vary in make-up and hence in response to chemical treatment according to several factors, such as its maturity and the method by which it may be isolated in chemical procedure We know, for example, that slow drying of a feed sample at room temperature gives considerably different values for its lignin than does the same chemical procedure preceded by rapid oven drying of the sample

Crampton-Whiting Scheme. A modification of this scheme was later proposed by Crampton and Whiting† which isolated approximately the same three fractions of the "other carbohydrate" scheme, but avoided the direct determination of lignin The general plan of this proposal is indicated by Fig 3-1

A comparison according to three methods of analysis among the

* *J Nut* V 15, p 383 (1938)
† *J Animal Sci*, V 2, p 278 (1942)



SOLUBLE ASH = [TOTAL ASH (FROM SEPARATE SAMPLE)] – [INSOLUBLE ASH]

SOLUBLE CARBOHYDRATE = [LIPID FREE RESIDUE I] – [INSOLUBLE RESIDUE II] – [SOLUBLE PROTEIN] – [SOLUBLE ASH]

CELLULOSE BY DIRECT ANALYSIS OF INSOLUBLE RESIDUE II

Fig. 3-1. *Diagrammatic scheme of analysis of carbohydrate portion of feeds.*

amounts of the presumably highly digestible carbohydrate portions—nitrogen-free extract vs other carbohydrate vs. soluble carbohydrate—of four rations is given in Table 3-2

TABLE 3-2 *Chemical Analysis of the Carbohydrate Fraction of Rations by Three Methods of Analysis*

Ration†	Standard method		Crampton Maynard method		Crampton Whiting sol CHO method	
	Nutrient	% composition	Nutrient	% composition	Nutrient	% composition
No 3 Feed Barley	NFE*	66	Other CHO*	59	Soluble CHO	63
	Crude fiber	6	Cellulose	5	Cellulose	5
			Lignin	7	Lignin*	4
No 1 Wheat Screenings	NFE*	66	Other CHO*	56	Soluble CHO	60
	Crude fiber	6	Cellulose	5	Cellulose	5
			Lignin	10	Lignin*	8
No 1 Feed Oats	NFE*	59	Other CHO*	48	Soluble CHO	55
	Crude fiber	11	Cellulose	11	Cellulose	10
			Lignin	10	Lignin*	6
No 3 Feed Oats	NFE*	51	Other CHO*	29	Soluble CHO	43
	Crude fiber	25	Cellulose	26	Cellulose	23
			Lignin	21	Lignin*	10

* By difference

† Rations were 85% of the basal feed shown plus 15% of a protein mineral vitamin supplement

NFE = Nitrogen free extract

CHO = Carbohydrate

The nitrogen-free extract is in every case larger than other carbohydrate with soluble carbohydrate intermediate The difference between the two latter lies almost entirely in the difference in the

apparent lignin. With feeds high in lignin the "lignin by difference" scheme yields figures for lignin in line with published data.

That the scheme succeeds in separating a highly and poorly digested fraction from the total carbohydrate is evident from Table 3-3.

TABLE 3-3 *Digestibility of the Carbohydrate Fraction of Rations Determined by Three Methods of Chemical Analysis*

Ration*	Standard method		Crampton-Maynard method		Crampton-Whiting Sol. CHO method	
	Nutrient	% Dig.	Nutrient	% Dig.	Nutrient	% Dig.
No. 3 Feed Barley	N.F.E.	80	Other CHO	89	Soluble CHO	83
	Crude fiber	6	Cellulose	−9	Cellulose	1
			Lignin	35	Lignin	7
	TDN	69	TDN	71	TDN	69
No. 1 Wheat Screenings	N.F.E.	76	Other CHO	86	Soluble CHO	82
	Crude fiber	6	Cellulose	−2	Cellulose	11
			Lignin	15	Lignin	−1
	TDN	78	TDN	68	TDN	67
No. 1 Feed Oats	N.F.E.	72	Other CHO	80	Soluble CHO	77
	Crude fiber	12	Cellulose	9	Cellulose	14
			Lignin	39	Lignin	14
	TDN	65	TDN	65	TDN	64
No. 3 Feed Oats	N.F.E.	25	Other CHO	23	Soluble CHO	28
	Crude fiber	7	Cellulose	4	Cellulose	9
			Lignin	31	Lignin	2
	TDN	26	TDN	26	TDN	23

* Rations were 85% of the basal feed shown plus 15% of a protein-mineral-vitamin supplement.

N.F.E. = Nitrogen-free extract.

CHO = Carbohydrate.

TDN = Total Digestible Nutrients.

Dig. = Digestibility.

Total Digestible Nutrient figures obtained in the case of the Crampton-Whiting scheme by omitting the lignin from consideration.

are not appreciably different in the three plans of carbohydrate partition

This plan has also been found in our laboratory to be adaptable for routine work When applied to feeds typical of those used in pig rations it appears to yield lignin values that are in closer agreement with other published values than were found with the formaldehyde method of lignin determination We have also found that the fractions isolated are of significantly different digestibility, and hence for practical purposes may be used as biological units in the chemical description of the feed

Starch Equivalent Values

While the Total Digestible Nutrient scheme of describing quantitatively the useful energy values of feeds was being developed in North America, Kellner, in Germany, was devising a somewhat different method of describing the energy value of feeds based also on the Weende analysis His feeding standard* appeared in 1905 in Germany and in English in 1909 Kellner objected to the Total Digestible Nutrient plan because it did not measure the energy actually available to the animal in that it neglected metabolic processes in which energy escaped in the urine and also as wasted heat

In order to arrive at the net energy which a feed might yield, Kellner fed adult oxen a maintenance ration and then determined that one pound of starch fed in excess of maintenance produced 0 248 lbs of body fat Other pure carbohydrates gave similar values But digestible true protein and digestible fat gave different values, as follows

Body fat produced per pound digestible nutrient	
from starch	0 248 lbs
from true protein	0 235 lbs
from ether extract	0 474-0 598 lbs

Kellner took the figure for body fat produced by starch as 1 and expressed the protein as $235/248 = 0\,9476$ units starch equivalent

* See *The Scientific Feeding of Animals* The Macmillan Co N Y (1913)

and ether extract as $.598/.248 = 2.41$ units starch equivalent. When expressed as percentages, protein had 94.76% and ether extract 241% of the value of starch in producing body gains in adult steers.

Experiments with actual feedstuffs revealed that ether extract did not produce the full predicted value, but instead varied from 191% for that of roughage to 212% for the fats of cereal grains. Experiments also showed that the net nutritive value of the variety of concentrate feeds was about the same as he had obtained from the pure nutrients when they were added separately to the maintenance rations.

On this basis, Kellner calculated the starch equivalent values for concentrate feeds from their proximate analysis. He found, however, that for feeds containing much crude fiber his starch equivalents were too high. As an adjustment he proposed a reduction of the computed value, accomplished by the use of an "evaluating factor," which was characteristic for feeds of differing fiber content.

The starch equivalent values for the proximate principles eventually arrived at were:

Dig. true protein	0.94
Dig. fat in fodders	1.91
Dig. fat in grains	2.12
Dig. fat in oily seeds	2.41
Dig. carbohydrate + fiber	1.00
Evaluating factors	95-30%

As an example of the computation we may use rapeseed cake.

Dig. true protein	$24.8 \times 0.94 = 23.3\%$	starch equivalent
Dig. fat	$6.3 \times 2.41 = 15.2$	starch equivalent
Carbohydrate	$20.5 \times 1.00 = 20.5$	starch equivalent
	59.0%	starch equivalent
Evaluating factor for fiber	95%	
	56%	starch value

This result we interpret to mean that it requires 100 lbs. of rapeseed cake, fed above maintenance, to yield as much energy to the body as 56 lbs. of starch.

TDN vs. Starch Equivalent. The essential differences between the TDN and the starch equivalents as measures of useful feed energy will be apparent if the equations are set down together

$$\text{TDN} = (\text{CHO} \times 1) + (\text{Protein} \times 1) + (\text{Fat} \times 2.25)$$

$$\text{Starch equivalent} = [(\text{CH}_2\text{O} \times 1) + (\text{True Protein} \times .94) + (\text{Fat} \times 2.41)] \times \text{Fiber correction}$$

Using these formulae, we calculate for rapeseed cake

$$\text{TDN} = 59.4\%$$

$$\text{Starch equivalent} = 56.0\%$$

We can see that as a description of the useful energy of a feed these two schemes are not markedly different

Direct Determination of Caloric Value

To avoid some of the difficulties and inaccuracies inherent in the proximate analysis for carbohydrate fractions, some laboratories are determining the gross caloric value of a feed by combustion in a bomb calorimeter Subsequent similar determinations on the fecal residues from such diets makes possible a correction of the gross caloric value for the apparent loss in digestion and results in a figure that has been called digestible calories

This term then becomes a measure comparable to total digestible nutrients for expressing the useful energy of feedstuffs With this procedure we need to make no assumptions concerning the source of the energy and, of course none of the errors inherent in determination of the proximate principles are involved in this procedure

Among the objections to the use of a bomb calorimeter for routine feed analysis has been its time consuming nature and the lack of a permanent record of the temperature changes These objections have been largely overcome in the author s laboratory by the use of a recording potentiometer equipped with a maganin nickel thermocouple The advantages afforded by the recording potentiometer are first the temperature change is easily determined mechanically and second a permanent record of the determ nations is made

The bomb is ignited with an electric ignition unit and is rotated in its water bath by an electric motor driving through an elastic band, as shown in Fig. 3-2.

The recording apparatus we use in our laboratory is a Brown Electronic Strip Chart Recorder and Indicating Potentiometer (Minneapolis-Honeywell Regulator Co. Model No. 153X11W-X-28P4, using Chart No. 5947-1). The scale is graduated from 18°C. to 28°C.,

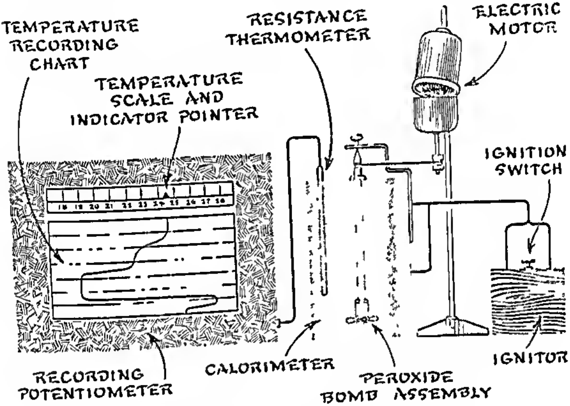


Fig. 3-2. *An improved method for determining bomb calorimeter values.*

and readings can be estimated with good accuracy to the nearest hundredth of a degree. The 6″ steel resistance thermometer is connected to the potentiometer with a 36″ conductor cable, both of which are supplied by the instrument manufacturer.

An analysis of variance was carried out on about 1000 determinations on feed and feces samples. The values determined when using the recording potentiometer with 95 samples showed a standard deviation which was 3.0 per cent of the mean. In a comparable set of values determined on some 900 samples, with the temperature

rise read from the usual type thermometer, the standard deviation was 3 4 per cent of the mean

Significance of the Energy Determination

Before turning to a consideration of methods of describing feeds with regard to protein we should indicate the reason that so much attention has been paid to ways of describing the energy values of feeds Practical experience has established that the most usual cause of below average performance of farm livestock is faulty feed intake In practical terms this is almost the same as saying "inadequate energy intake," for unless there is a marked difference in fat content and to a lesser extent in protein level, the dry matter of different feeds contains about the same gross energy Differences in *available* energy are likely to be small between comparable rations, since they will usually be of similar protein levels and of much the same overall digestibility

Furthermore, altering feed intake not only alters energy intake but that of all other nutrients of the ration

The energy need of an animal may be estimated by calorimeter studies or by correlating their performance with differing levels of energy intake

In either case it becomes necessary to know the usable energy of feeds and feed mixtures to be able to adjust feeding practice to meet the requirements of the animal fed Too liberal intake of digestible energy leads to body fat deposition which may or may not be important or desirable, while too meager allowances limit performance of functions requiring energy If the energy restriction is effected by feed restriction it also may mean inadequate intake of protein, minerals and vitamins, if these have been adjusted in concentration in the ration to correspond to the energy requirement

Thus we might truthfully say that a satisfactory working knowledge of the usable energy of feeds is the starting point in the successful use of feeds It is at the same time one of the difficult things to come by

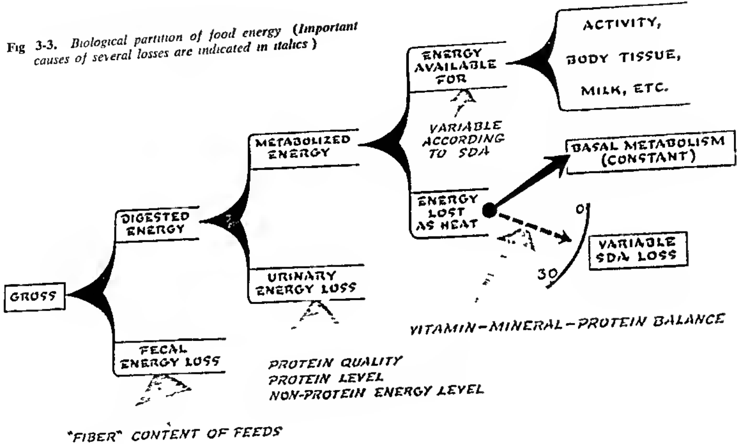
Feed Efficiency

Another term we use to describe the usefulness of feeds is *feed efficiency*. Inasmuch as this term has certain limitations, it may be well to discuss the nature of the term.

Trials that have as their objective the evaluation of the value of feeds or combinations of feeds, ordinarily use live weight gains and feed consumption records as the principal criteria. The magnitude of the gains made by animals on such trials is undoubtedly influenced partly by the quantities of the ration they have consumed and partly by the nature of that ration. If we divide the gain figure by the feed consumption figure, our calculation, "gain produced per unit of feed," has been taken as a method of adjusting the gain for equal feed intake. Our assumption has been that any difference in gain that remains after such adjustment is legitimately credited to differences in kind of feed. The numerical value of such a ratio is frequently used as a quantitative measure of feed efficiency. There are two fundamental weaknesses of this use of such figures. One of these is statistical and the other is biological.

In the usual calculation of the gain–feed ratio, the biological importance of the amount of feed voluntarily eaten is sometimes minimized, if not altogether overlooked. Perhaps some of this is due to careless thinking as to the causes of variations in feed intake. The willingness of animals to eat and the extent to which they will consume food are in part regulated by the nutritional character of the diet or perhaps more fundamentally by the state of intermediary metabolism. An outright nutrient deficiency, or a nutritionally significant imbalance in nutritients, may be expected to disturb intermediary metabolism. It is a recognized fact, established by experimental evidence, that imbalances caused by such factors as excessive quantities of protein, or a deficiency of some Vitamin B-complex member, or by restriction of water, etc., actually result in an increased total heat loss. And, since the basal metabolism is a constant, this must be a reflection of increased specific dynamic action. Similarly,

Fig 3-3. Biological partition of food energy (*Important causes of several losses are indicated in italics*)



as the diet becomes more perfectly adjusted to the requirements of the moment, the specific dynamic action declines. In any case, any increase in heat loss means a reduction in the energy available to the body for its maintenance or for productive purposes. This may be diagrammed as in Fig. 3-3.

It appears that the body's defense mechanism against the ingestion of materials that the body disposes of only at an extra energy cost is usually reduced appetite and the consequent reduction of food intake. Therefore those quantitative differences that animals exhibit in feed intake become an important index of the nutritional properties or adequacies of the feed or of the ration. It is almost universally true that nutritionally poor diets are consumed in smaller quantities than are the same diets made adequate by suitable amendments. Consequently, when we adjust gains to equal feed intake and judge feed efficiency from such calculations, we should not forget the importance of the actual feed intake as a fundamental index of nutritional value.

Where differences in feed intake between comparative lots are relatively small, feed efficiency established by comparing gains per unit of feed eaten or feed required to produce a unit of gain may be a highly useful procedure. If, however, there is a wide discrepancy in feed intake, then simple comparison of the gain–feed ratios may lead to implications that are not justified biologically.

These implications raise the statistical side of the question. Calculation of the gain–feed ratio implies that gain is directly proportional to feed intake over the whole range of intake from zero to whatever is maximum. Biologically, such an assumption is obviously untrue, because some of the feed consumed does not produce gain, but must be used for maintenance of weight already attained. If we desire to eliminate the effects of differing feed intake on gains, it is statistically more acceptable to adjust gains tu an equal feed intake by regression than by simple ratio, and it would seem logical in any given test to adjust the gains of different comparable lots to the average feed intake of the whole test. This statistical device is relatively simple of calculation and permits a more accurate measure of the differences

in gain from causes other than variability in feed intake than is possible by the simple gain–feed ratio.

While we cannot at this point give consideration to the mathematics involved, it may be useful to present a graph of the results of an analysis of a factorial test intended to measure the relative

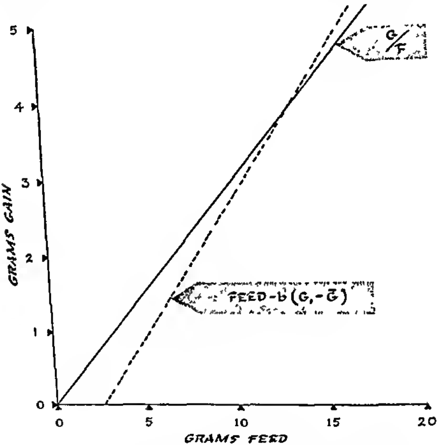


Fig. 3-4. *Grain-feed ratios by simple proportion and by regression.*

usefulness of feeds of animal origin and those of plant origin as sources of protein for growing rats.

The gain figures and the feed consumption figures have been used in the one case to calculate feed efficiency as a gain–feed ratio (see Fig 3-4). This is shown in Curve A. The same data are also used to

calculate the regression of gain on feed and the regression line is shown as Curve B

Note that these two curves cross at a point that represents the mean feed and the mean gain for the test You can also see that either method of adjusting gains to equal feed will give about the same answer for those groups that are close to the mean, but for groups that deviate significantly from the mean there will be an increasing error if the simple gain–feed ratio is used as the measure of feed efficiency Curve B indicates that in this test approximately 2½ grams of feed produced no gain, it is presumably the quantity of feed that was sufficient to maintain the animals The efficiency with which feed did produce gain is, then, indicated by the slope of Curve B, which is greater than that of Curve A

Another comment may be worthwhile in connection with the interpretation of any measure of feed efficiency that is calculated entirely from the gain and from the feed consumed Inasmuch as more rapid gain relative to feed intake gives a figure indicating increased efficiency, it is very easy to fall into the error of assuming that in all cases those feeds that induce the most rapid gains are necessarily feeds of highest feeding value Obviously such feeds are of highest feed efficiency if efficiency means only gain per unit of feed eaten This meaning is probably the objective with dairy cattle feeding and perhaps with the feeding of horses, where maximum production per unit of feed used or maintenance of weight per unit of feed used is the economically important factor

In the case of bacon hogs, however, the feed that produces the greatest gain per unit of feed often is not the desirable one If such feeds are fed *ad libitum* in the finishing ration of bacon pigs they result in overfat carcasses, which are penalized both by consumer demand and by dollar return to the producer It is, of course, possible to restrict the allowance of such feeds and, consequently, capitalize on their high available energy content Restricting feed, however, requires individual penning, which is not practical for the pig feeder If group-fed pigs have their total feed limited in amount, the usual result is uneven performance of the group Some pigs will be more

aggressive and still be full-fed, while the more timid animals will be undesirably restricted in intake.

The practical solution of this for the pig feeder is to introduce less efficient feeds—feeds that have lower energy value per pound; feeds that are bulky per unit of their available energy. Such feeds must be eaten in considerably larger amounts to produce the same live weight gain that heavier higher energy feeds will produce. Such feeds will also be less efficient in producing gains but more efficient in producing desirable carcass. Thus feed efficiency must be interpreted in terms of the result desired.

PROBLEMS

1. In order to provide each 100 Calories for basal metabolism, how much difference in the metabolizable calorie requirement would it make to so balance the ration that the SDA was reduced from a value of 25 to 5% of the total heat loss? Assume that the caloric demand for the non-productive activity of an idle adult is about 25 Calories for each 100 Calories of basal metabolism Can you suggest economical conditions where it would not pay to feed a "balanced ration"?

2 Given a ration of the following specifications·

	% composition by weight	Calories per gram	% digestibility
Protein	15	5 6	75
Fat	3	9 3	70
Carbohydrate	70	4 0	85

Assume that when fed to an animal the ration efficiency was 30 units gain per 100 units air-dry feed consumed What would you expect, other factors constant, would be the efficiency if the fat content were increased to 20% at the expense of carbohydrate? If equal quantities of digestible calories were consumed how much difference (in %) would there be in daily feed intake?

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CHAPTER 4

Schemes of Describing Protein Value of Feeds

Measures of Protein Quality

SOMEWHAT ANALOGOUS to the problem of describing the overall available energy value of feeds is that of the nutritive worth of the protein complex It is generally accepted today that the usefulness of feeds as sources of protein depends primarily on two factors, viz, the total concentration of the proteins (i e, nitrogen × 6 25) and the distribution of the amino acids making up the proteins There is ample evidence that imbalance between amino acids of the ration results in inadequate protein nutrition This deficiency may be reflected only as a minor decrease in feed efficiency for some such function as growth or milk production, or it may be severe enough to cause the death of the animal

The relative usefulness of the protein of a particular feed in meeting the animal s protein (nitrogen) needs is often referred to as its quality, and terms that are quantitatively descriptive of protein quality include, *biological value, protein value, chemical score* and *replacement value* We shall define and describe these terms at this point

Biological Value of Proteins. The concept of biological value as applied quantitatively to the nitrogen portion of feeds is essentially

as a figure expressing the fraction of the digested protein which, in growing animals, cannot be accounted for through urinary excretion; it is a measure of the fraction of the digested feed protein that is retained in the body. We assume that amounts retained reflect accurately a "perfect" assortment of amino acids. Surpluses of absorbed individual amino acids remaining above the maximum used in making up this "perfect" assortment are presumed to be deaminized and the nitrogen component excreted via the urine. Thus biological value (B.V.) is precisely defined by its (Thomas-Mitchell)* formula:

$$\% \text{ B.V.} = 100 \times \frac{\text{N intake} - [(\text{Feces N} - \text{Metabolic N}) + (\text{Urine N} - \text{End N})]}{\text{N intake} - (\text{Feces N} - \text{Metabolic N})}$$

Note that the total feces nitrogen is corrected for the metabolic fecal nitrogen and the urinary excretion for the endogenous nitrogen. We presume that the metabolic fecal nitrogen is not a direct dietary residue, and hence we must disregard it in measuring the true digestibility of the dietary intake. We also assume that "Folin's" endogenous urinary nitrogen measures normal wear and tear of nitrogenous body tissue and does not, therefore, represent surpluses of amino acids discarded because of imbalance. While Folin's conception of the significance of endogenous and exogenous urinary nitrogen is not altogether accepted today, the use of the "endogenous" excretion in obtaining a biological value by this method is necessary. Perhaps we should not concern ourselves too seriously over the theory's shortcomings, as other methods of measuring the quality of food protein are now more often employed.

The formula for biological value more readily used is expressed in a slightly different form, obtained from the original by permutation, and usually written as:

$$\% \text{ B.V.} = 100 - \frac{(\text{Urinary N} - \text{Endogenous N}) \times 100}{\text{N intake} - (\text{Feces N} - \text{Metabolic N})}$$

The so-called Thomas-Mitchell biological value as a practical measure of the quality of a protein has two serious limitations. The

* *J. Biol. Chem.*, V. 58, p. 873 (1924).

first is the difficulty of obtaining a measure of the endogenous urinary nitrogen, and to a lesser extent, the metabolic fecal nitrogen. In practice the former is sometimes calculated on the basis of body size according to the equation.

$$\text{Milligrams Endogenous Urinary Nitrogen} = 146(W_{kg}{}^{.75})$$

If the values for endogenous urinary N are to be determined experimentally, it is necessary to prepare and feed a nitrogen-free diet To prepare such a diet that will be voluntarily eaten for long enough to obtain the necessary data is a practical impossibility with any but laboratory animals

The second difficulty arises from the fact that the level of nitrogen (protein) fed modifies the calculated biological value independently of the amino acid balance, because deamination appears to proceed somewhat according to the law of mass action Thus to obtain maximum biological value there must be a minimum of protein furnished This automatically means that production rations, including those for growth, where liberal protein feeding is necessary for maximum performance, show low biological values as compared to maintenance allowances Hence biological value data for individual feeds will change according to the rations in which they are used Biological values are constants only if the protein is used entirely for maintenance In order to compare such figures for different feeds they must have been determined at the same protein levels of intake, and to standardize this, such rations often are adjusted to 10% protein

The utilization of high biological value ration proteins in actual feeding according to the level of protein ingested is shown in Fig 4-1

Here we should note that when up to 40 gms of whole egg protein is ingested per day, essentially all of it is used as protein At 5 gms intake all is used for maintenance But as intake rises to 10 gms per day only 35% of it will be used for maintenance with 65% being used for tissue synthesis (i e , as protein gain to the body) Thus at this level the B V is 100% With increasing intake the curve for the proportion used for maintenance steadily declines while the protein gain rises These two uses account for all the

intake until the daily consumption becomes 38 to 40 gms., which appears to be the maximum that can be utilized as protein. (Note that the protein is whole egg protein, which is considered to have a practically perfect distribution of amino acids).

Above this level there is a surplus that will be deaminized with a consequent rise in exogenous urinary nitrogen and an increase in specific dynamic heat loss. Now since less than all the protein in-

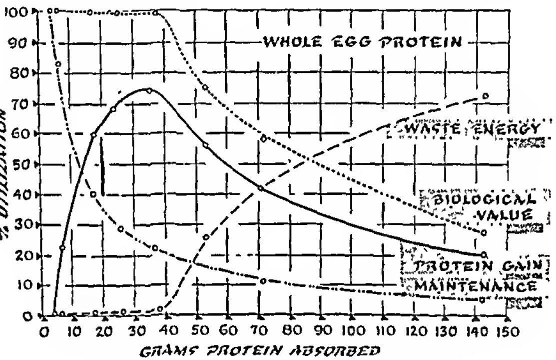

Fig. 4-1. *Effect of level of protein ingestion on its utilization. (From Barnes, R. H. et al, J. Nut., V. 32, p. 535-548, 1946.)*

gested remains in the body (i.e., for maintenance plus protein gain), the biological value declines. Thus, whereas at 38 gms. intake the biological value is about 100, at 70 gms., it is only 60, with 40% of it being metabolized for other purposes.

We should remember that the category marked on the graph as protein gain "refers to all utilization of protein for tissue synthesis other than the maintenance component." Hence, it includes body tissue as growth and production as milk, eggs, or wool. This graph makes it clear that age, class of animal, and the production involved all influence the effective apparent binlogical value of n protein in addition to any "abnormalities" in amino acid balance.

Biological value figures are not now used in applied feeding, though they have served a useful purpose in establishing differences between protein sources as to nutritional usefulness, and undoubtedly their limitations stimulated the development of more satisfactory methods of description. The *term*, biological value, however, is still used to denote protein quality.

Protein Replacement Value. Because of the limitations of the Thomas Mitchell biological values, Merlin* at Rochester University devised a slightly different measurement that indicates the extent to which a given protein can replace some "standard" protein in terms of nitrogen balance. His formula for obtaining this measurement is

% Replacement Value =

$$100 - \left[\frac{\text{Nitrogen Balance}_1 - \text{Nitrogen Balance}_2}{\text{Nitrogen Intake}_1}\right] \times 100$$

Two nitrogen balances (see Chart 4-A) are conducted with nitrogen intakes essentially equal. The numerical difference between the two balances is expressed as a percentage of the nitrogen intake of the test having the larger nitrogen consumption. (If the intakes are nearly equal, the mean intake of the two tests may be used.) As measured by nitrogen retention, this percentage figure represents the extent to which the one protein has failed biologically to match the other. The compliment of this percentage figure is the replacement value (R.V.) for the protein being examined.

An example may clarify the calculations. Assume a comparison between two rations, the protein of which in one is from whole egg, and in the other from soybean oilmeal. The daily nitrogen intake in each ration is 50 gms. and the nitrogen balances are +20 and +16 gms., respectively.

We then calculate:

$$\begin{aligned}\text{Egg R.V. of soybean protein} &= 100 - \left(\frac{20-16}{50}\right) \times 100\\ &= 100 - \left(\frac{400}{50}\right)\\ &= 80\%\end{aligned}$$

* J. Nut. V. 5. p. 15 (1938).

Thus we see that soybean protein failed to equal egg protein by $\left(\frac{20-16}{50}\right) \times 100$, or 20%; and so we say it has an egg replacement value of 80%.

The formula for replacement value is sometimes written:

$$\text{R.V.} = 100 - \left[\frac{\text{Difference in Nitrogen Balance}}{\text{Nitrogen Intake}}\right] \times 100$$

CHART 4-A *Typical Work Sheet for N_2 Balance*

	Food eaten (24 hr. D.M. basis)	as recorded during the test period ÷ days	1767 gms.
Intake Data	% N_2 in dry matter	from chemical analysis of a sample of the feed	3.01%
	Gms. N_2 intake (24 hr. basis)	1767 × .0301	53.2 gms.
	Gms. excreted (24 hr. D.M. basis)	moist feces × % H_2O ÷ days	556 gms.
Output Feces	% N_2 in dry matter	from chemical analysis of composited aliquots of daily collection	2.55%
	Gms. N_2 voided in feces	556 × .0255	14.2 gms.
	Volume urine (24 hr. basis)	Total ml. urine voided for test period ÷ days	3712 ml.
Output Urine	% N_2 in urine	by chemical analysis on composited daily aliquots	0.52%
	Gms. N_2 voided in urine	3712 × .0052	19.1 gms.
Balance gms /24 hrs.		53.2 − (14.2 + 19.1)	+19.9 gms.

Replacement values are free from implications concerning protein metabolism (see *Biological Value of Protein*); may be employed in a relative sense to describe the relative usefulness of any two proteins used under comparable conditions; and if tested against egg or milk proteins (whose biological values are nearly 100) have about the same numerical value as biological values determined under optimum conditions.

The interpretation of replacement value figures in describing protein

quality requires a simultaneous consideration of the apparent digestibility of the protein, since a nitrogen balance is dependent on both digestibility and intermediary metabolism It is theoretically possible for two proteins, when measured each against egg protein, to have similar replacement values due in the one case to high utilization of a relatively poorly digested fraction, while in the other there might be a high digestibility but poor metabolic utilization In practice, however, we find more often that poor digestibility is correlated with low metabolic use, or else the digestibility is essentially the same in comparative cases

A series of tests in which egg replacement values of cereal protein were determined with rats will illustrate the type of data to be expected with this technique (see Table 4 1) These data indicate that cream-of-wheat protein is as fully digested as is egg protein but has only 72% the overall biological value Shredded wheat

TABLE 4-1 *Egg Replacement Values of Cereal Foods as Affected by Heating Cereals*

	Nitrogen output			Apparent digestibility	N intake	N balance	Egg N intake	RV
	Urine	Fecal	Total					
		g/day			g/day	g/day	g/day	
Egg	4.49	.97	5.46	83	5.95	+.49	4.64	
Precooked oats	4.60	1.34	5.94	77	5.84	−.10		87*
					Diff =	−.59		
Egg	4.49	.78	5.27	86	5.85	+.58	4.56	
Cream of wheat	5.66	.89	6.55	85	5.87	−.68		72
					Diff =	−1.26		
Egg	4.40	.89	5.29	84	5.83	+.54	4.55	
Shredded wheat	4.74	2.00	6.74	66	5.84	−.90		68
					Diff	−1.44		
Egg	4.38	.81	5.17	86	5.88	+.69	4.59	
Puffed wheat	5.37	1.85	7.22	69	5.94	−1.28		57
					Diff =	−1.97		

$* \ 100 - \frac{.59 \times 100}{4.64} = 87\%$ RV

and puffed wheat are about equally less well digested than egg but the lower replacement value of the more intensely heated puffed wheat indicates a further damage to the amino acids from the processing

Another example of the use of replacement values and digestibility data in estimating the quality of protein of a feedstuff is found in studies at Macdonald College of Malt sprouts as a hog feed In one of the balance trials the Linseed oilmeal protein replacement value of Malt sprout protein was determined at three ration protein levels with data as shown in Table 4-2

TABLE 4-2 *Nitrogen Balance and Protein Replacement Values Between Rations of Corn Plus Malt Sprouts vs Linseed Oilmeal*

	10 3% protein		12 3% protein		14 2% protein	
	Malt sprout ration	Linseed oilmeal ration	Malt sprout ration	Linseed oilmeal ration	Malt sprout ration	Linseed oilmeal ration
N_2 balance*	5 23 gm	5 02	5 55	7 20	5 02	7 34
% total N_2 excretion as						
Urine N_2	70%	78	68	77	65	77
Fecal N_2	30%	22	32	23	35	23
Replacement value of malt sprouts protein	104%		84		84	
% of total N_2 supplied by supplements	27%		45		58	

* Average of 4 pigs per group

In these data (Tables 4-2 and 4-3) we find a situation where the protein of a corn-malt sprouts ration is not the equal in terms of replacement value to a corn linseed oilmeal ration, excepting when only about a quarter of the total ration protein is derived from the supplements Further examination of the data reveal that the proportion of the digested protein that was excreted in the urine was essentially the same in all tests The conclusion is, therefore, that

the poorer digestibility of the malt sprout protein and not its amino acid balance is responsible for the overall lower replacement value of malt sprouts in the pig ration when large enough quantities are used to provide 50% or more of the total ration protein

TABLE 4-3 *Urinary N_2 as a per Cent of Total N_2 Digested*

% protein in ration	% of total N_2 supplied by supplements	Urinary N_2 as % of total N_2 digested: Malt sprout rations	Linseed oilmeal rations
10.3%	27	66	70
12.3%	45	69	65
14.2%	58	74	68
	Average	70%	68%

Replacement values are useful in comparing protein values under nutritional states other than those in which protein is the limiting nutritional factor This method is nevertheless a biological method and hence is time consuming, it is subject to difficult interpretation because of animal variability, and finally it is an overall measurement that does not indicate the specific cause of the figure obtained and hence gives no clue directly as to how to improve a protein having an undesirably low value

Chemical Scores for Protein To overcome the economic limitations of biological methods of describing protein quality, two schemes have been proposed, both of which yield a numerical value for quality arrived at by a consideration of the relative amounts of the amino acids present in the protein as determined by chemical (or in some cases biological) analysis

*Block and Mitchell** conceived protein quality as the consequence primarily of a relative shortage of some one essential amino acid They took the make up of whole egg protein as the standard or ideal, and determined the percentage by which the amino acids of a com-

* *Nut Abst and Revs* V 16 p 249 (1947)

parative protein were individually deficient or in excess of those of the standard (see Table 4-4) Excesses were considered innocuous The amino acid present in greatest deficit was considered the limiting amino acid and the complement of its percentage deficit was their *chemical score* for that protein Thus a protein showing lysine to be only 40% of that in egg protein would have a chemical score of 60%, providing this was the amino acid in greatest deficit

TABLE 4-4 *Calculation of Mitchell's "Chemical Score" for Wheat* as an Index of Protein Quality*

Amino Acids			
Name	% in egg protein	% in wheat protein	% deficiency in wheat
Arginine	6 4	4 2	−34
Histidine	2 1	2 1	0
Lysine	7 2	2 7	−63
Tyrosine	4 5	4 4	−2
Tryptophane	1 5	1 2	−20
Phenylalanine	6 3	5 7	−10
Cystine	2 4	1 8	−25
Methionine	4 1	2 5	−39
Cystine + Methionine	6 5	4 3	−34
Threonine	4 9	3 3	−33
Leucine	9 2	6 8	−26
Isoleucine	8 0	3 6	−55
Valine	7 3	4 5	−38

* ' Chemical Score for wheat based on amino acid in greatest deficit is 100 − 63 = 37

An extensive series of feeding trials with rats established that the chemical scores for a considerable range of proteins correlated well with the relative values of these proteins for growth, and also that they correlated with biological values The correlations are by no means perfect, though they are statistically significant

On theoretical grounds we might argue that nutritional relationships among food proteins should be revealed more easily by a determination of amino acid composition than by biological estima-

tion Nevertheless, the variability of results was found to be relatively large, so that while chemical score appears to be a useful measurement for separating proteins into categories of usefulness, there are likely to be discrepancies in individual cases that would be of practical importance Another problem involves the protein that is deficient in varying degrees in several essential amino acids Correction of one deficiency still leaves a combinaiton that is biologically imperfect

Oser's EAA Index Method of Chemical Evaluation. Oser,* while approving the general principle of chemical score as outlined by Mitchell and Block, takes the stand that all essential amino acids should be considered rather than the single one that is in maximum deficit with respect to some Standard His argument is based on the view that each essential amino acid is essential in its own right—that each is equally essential Incidentally, this view neglects the possibility of differential rates of synthesis for those amino acids that can be thus formed, though at a suboptimum rate

The picture of protein quality in respect to the 10 amino acids that are commonly classed as essential may be obtained for milk, beef, and for two cereal proteins, wheat and corn, by means of a graph of their respective egg ratios (see Fig 4-2) The egg ratio is merely the percentage by which the amino acid in a feed protein departs from that found in whole egg protein with excesses taken as 100% The order of arranging the essential amino acids is immaterial, but in this example it follows the increasing deficiency in wheat flour

In this graph the lowest point for each of the four example proteins would represent the Mitchell Block chemical score

When we examine the common feeds by this method the data suggest what is well-established analytically, that the protein complex of the cereal grains as a class is of lower biological value than egg protein and other animal proteins because of shortages in descending order of lysine, tryptophane, isoleucine, valine, arginine, and methionine plus cystine Supplementation with lysine, while correcting

* *J Amer Dietetic Assn* V 27 p 396 (1951)

the first deficiency, still leaves several other amino acids to become, in turn, the limiting factors in biological quality.

In order to take into account all of the essential amino acids, Oser has proposed an Essential Amino Acid Index, which is the

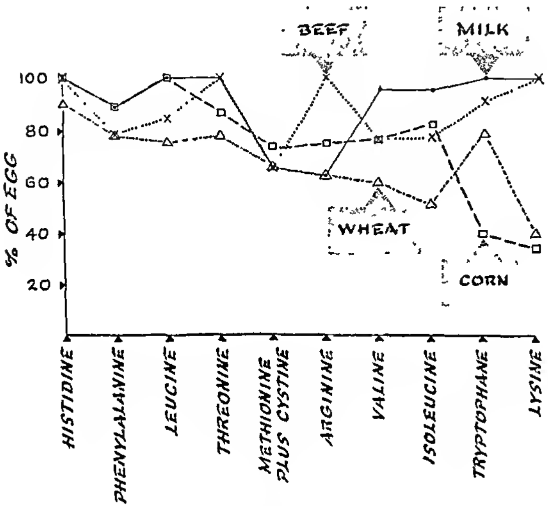

Fig. 4-2. *Trend of "chemical scores" of certain protein sources.* (*Adapted from Oser,* J. Amer. Dietetic Assn., *May, 1951.*)

geometric mean of the ten egg ratios found in comparing the content of the ten essential amino acids in a feed protein with that found in whole egg protein. Algebraically the index is expressed as:

$$\text{EAA Index} = \sqrt[10]{\frac{100a}{a_e} \times \frac{100b}{b_e} \cdots \frac{100j}{j_e}}$$

in which, a b j are the per cent of essential amino acids in the food protein and a_e b_e, —j_e are the per cent of the respective amino acids in whole egg protein

For computation it is convenient to express the equation in logarithms as follows

$$\log \text{EAA Index} = \frac{1}{10}\left(\log \frac{100a}{a_e} + \log \frac{100b}{b_e} \qquad + \log \frac{100j}{j_e}\right)$$

An example of Oser's computation of white flour protein is shown in Table 4-5

TABLE 4-5 *Calculation of Oser's EAA Index for White Flour Protein*

Amino acid	Egg ratio	Log egg ratio
Lysine	27 1	1.4330
Tryptophene	53.5	1.7267
Isoleucine	54 5	1.7364
Valine	56 9	1.7551
Arginine	59 1	1.7716
Methionine plus cystine	60 9	1.7788
Threonine	62 8	1.7980
Leucine	76 1	1 8814
Phenylalanine	87.3	1 9410
Histidine	91.7	1 9624
$\frac{1}{10}$ × Sum of logs		1.7784
EAA Index (i e., antilog)		60.3

Oser s indices are closely correlated with the Mitchell–Block biological values and the numerical values are in closer agreement with these values than are those of chemical scores and biological values Thus biologic values can be predicted from the EAA Index with reasonable accuracy, the mean deviation of the Index from B V being of the order of + 2 8 ± 4

With this scheme of describing protein quality we can estimate the effect of fortification of proteins with one or more pure amino

acids, or the effect of combining proteins of dissimilar amino acid distribution In this respect it would appear to be more useful than the Mitchell–Block chemical score

However, we should point out that proteins of quite different amino acid make-up may have identical EAA Index rating For example, a protein with a very marked relative shortage of one or two amino acids might show an EAA Index no lower than another with a more balanced assortment With the first protein strong fortification with the one or two deficient acids would be called for to raise the nutritional value, whereas with the second such amendments would be only partially effective

Thus such methods require more than the Index value alone if they are adequately to describe the quality of protein of a feed

Application of Protein Quality in Feeding Practice

We sometimes find it useful after being absorbed in some specific feature of a problem to sit back and have an overall look at the situation in order to establish perspective and balance This procedure applies particularly well to the question of protein quality

That there are a number of amino acids needed for the synthesis of the protein of one tissue or another in the body is unquestioned Some, perhaps half of these the body can readily put together from stored amino radicals plus non-nitrogenous fragments of carbohydrate or fatty acid metabolism The others must be supplied to the blood stream preformed, and in quantities and assortments dependent upon the kind and extent of the physiological functions requiring them

From this point on we must recognize species differences Herbivorous animals, beyond the early juvenile ages, are able through the role of their symbiotic microflora, to arrange for the necessary supply of these essential amino acids almost, if, indeed, not entirely, independently of the nature of the nitrogen of the ration Inorganic sources such as ammonium sulfate or urea nitrogen are apparently as acceptable as protein nitrogen to these organisms for their synthesis of the whole assortment of amino acids

And so from the feeders standpoint, description, either qualitative

or quantitative, of the quality of the protein of feeds are of no particular importance in the preparation of rations for, or in the feeding of herbivorous livestock A simple statement of protein content indicated by (N × 6 25) is all that he needs This means that we do not need to concern ourselves with the protein quality of any roughages nor of any concentrates that are of use only in the feeding of herbivors

For other species, the omnivors and carnivors, however, the assortment of amino acids needed is not constant, but depends on the physiological activity at the time Digestive enzymes are of different amino acid composition from the enzyme myosin or from milk protein or that of wool or hair Not only are the rates and extent of these demands for amino acids fluctuating hour by hour but the special functions of some of them such as of detoxication and of the production of immune bodies are not continuous Thus there cannot be a fixed biological quality of any protein

The question thus arises as to whether for most practical feeding, one can ever hope to provide animals with a perfect protein Or whether if it were possible, it would be feasible For a herd of swine, for example, how many different feed mixtures will it be either economical or even feasible to employ?

One wonders if it will not suffice to group feedstuffs into categories as to the nature of their protein, so that those short of lysine are separated from those lacking sulfur-containing acids, etc Such a practice would be a guide in feed substitution to prevent the unwitting choice of several feeds with a common deficiency, as well as a help in obtaining the benefits of the supplementary values of rich sources of any acids deficient in certain feeds

After all except for cases of gross deficiency of essential amino acids the chief advantages of using rations with proteins of high biologic values is in the possibility of using lower levels of total protein—an economic problem This possible saving must therefore be balanced against the cost of restricting feed selection in ration formulation as well as the practicability of adjusting feeding practice critically enough to realize any difference in potential efficiency of the ration of the higher protein quality

Supplementary Values of Protein

The biological value of a digestible protein fed in amounts not exceeding requirements and in an energy adequate diet, it is generally agreed, depends primarily on its assortment of essential amino acids As proteins of increasingly poorer biological value are fed, there are correspondingly larger and larger quantities of surplus amino acids that will not be utilized to meet protein needs of the body Rather, they may be deaminized and eventually oxidized for their energy

If, however, two or more proteins, each of *imperfect biological* value because of different specific amino acid shortages, are combined in the ration, there may be mutual amino acid supplementation of each of the original proteins with a consequent enhancement of the biological value of the mixture over that of the separate components

We can illustrate the situation as it is believed to exist by a ridiculously over-simplified and, of course, purely hypothetical example Assume that some essential protein tissue, as an enzyme, consists of five amino acids *A, B, C, D, E,* in the proportions of 48, 10, 4, 32, 6 We might describe such a tissue as

$$A_{48}\, B_{10}\, C_4\, D_{32}\, E_6$$

and if such an assortment were supplied to the animal (as the ration protein), we might expect all of it to be used That is, it would have a biological value of 100%

Now assume that we offer this animal a protein of the following description

$$\text{Protein I} \quad A_2\;\; B_{28}\, C_2\, D_{34}\, E_{10}$$

Its usefulness is reduced because of a relative shortage of *A* and *C* As compared to the ideal, this protein will permit only half as much of the enzyme to be synthesized The biological value of half of this protein will be 100 but of the whole protein it will be only 50 The remaining assortment of amino acids have no biological value as far as the synthesis of our enzyme is concerned, because there is no *C* acid For example,

Used for synthesis $A_{24}\,B_5\,C_2\,D_{16}\,E_3 = 50\%$ (Biological Value 100)
Used for energy $A_2\,B_{23}\,C_0\,D_{18}\,E_7 = 50\%$ (Biological Value 0)

This residue of amino acids is often referred to as the supplementary fraction of a protein. It is the total of the amino acids that could not be used in protein tissue synthesis because of the absence of one or more essential ones.

One of two things can be done to salvage some or all of this residue. Pure amino acids may be fed with the protein to correct its deficiency of acids A and C. Such amendments to correct methionine shortage are now economical and commonly employed where this deficiency is the cause of the low biological value. The practical usefulness of this procedure generally is limited by presently available knowledge of specific requirements and of the amino acid assortments of many feeds. Experimentally, the consequences of such amendments have been demonstrated by Baumann* who fed mice on a purified diet, excepting for protein that was derived in different tests from casein, fibrin, or from oxidized casein. The results may be summarized in tabular form as in Table 4-6.

TABLE 4-6 *Effect of Supplementing a Deficient Protein with the Missing Amino Acids*

Protein fed	Supplement	% of ingested amino acids excreted in urine	
Casein	none	3.9%	
Fibrin	none	1.5%	
Oxidized casein	Methionine, Cystine, Tryptophane	10% or less	
Oxidized casein	Methionine, Cystine	13.48%	Av. of 25% of amino acids other than the one deficient
Oxidized casein	Tryptophane, Cystine	10.38%	

* *J. Biol. Chem.* V. 168, p. 27 (1947).

Evidently when a protein low in some amino acid is fed, only that quantity of the other amino acids needed to match the one in short supply can be used, and the surplus is excreted in the urine. Thus, in a tryptophane + methionine deficient protein high excretions of other amino acids occur. This ceases when tryptophane + methionine is added to the diet. In these tests the excretion fell from an average of 25% to about 10% when the amino acid deficiency was made good. The test also indicated that the fate of the surplus amino acids from deficient protein is not entirely one of deamination and subsequent oxidation for energy.

The second and more often used procedure for improving the biological value of a feed mixture is that of employing protein mixtures. If two or more proteins of low biological value but of differing amino acid assortment are combined, they may provide mutual supplementation of deficiencies.

To return to our example, assume we have available a second protein as follows:

$$\text{Protein II} \quad A_{46}B_{18}C_{6}D_{20}E_{10} = 100$$

This protein has a surplus of C but still is of relatively low biological value, as we can see if we compare it to the ideal:

$$\text{Used for synthesis } A_{30}\,B_{7}\,C_{3}\,D_{20}\,E_{4} = 64\%$$
$$\text{Used for energy } A_{16}\,B_{11}\,C_{3}\,D_{0}\,E_{6} = 36\%$$

Thus, our protein II has a biological value of 64% as compared to protein I, and correspondingly a smaller wastage of amino acids. Furthermore, this wastage differs from that of protein I. The residue from I contains no C, while that from II contains no D. Besides that, protein II residue has a considerable quantity of A, while that of protein I has almost none. Mixing these two proteins should, therefore, result in a biological value of the combination greater than the mean biological value of proteins I + II of $\frac{50 + 64}{2} = 57$.

In terms of our example we may illustrate by mixing equal quantities of proteins I and II and comparing the average amino acid assortment with our ideal:

Ideal	$A_{48}\,B_{10}\,C_4\,D_{32}\,E_6$
Protein I	$A_{26}\,B_{28}\,C_2\,D_{34}\,E_{10}$
II	$A_{46}\,B_{18}\,C_6\,D_{20}\,E_{10}$
Mixture of I + II	$A_{36}\,B_{23}\,C_4\,D_{27}\,E_{10}$
Used for synthesis	$A_{36}\,B_8\,C_3\,D_{24}\,E_5 = 75\%$
Used for energy	$A_0\,B_{15}\,C_1\,D_3\,E_5 = 25\%$

Thus by mixing proteins I and II we obtain a protein complex, 75% of which may be used for our enzyme synthesis as compared to 57% expected as the mean of the two proteins we have employed

Mitchell gives a numerical rating for the supplementary value of the protein of feeds It is the complement of the biological value, i e , it is the percentage of the digested protein that is not usable for the protein needs of the body In our example, protein I would have a supplementary value of 50%, protein II one of 36%, while that of the mixture would be 25%

It does not always follow that proteins having the lowest biological values will in actual fact have the greatest supplementary value, for obviously the enhancement of biological values by mixtures depends on mutual supplementation of amino acid deficiencies Proteins with quantitatively similar deficiencies will not likely show effective supplementary values if combined Thus, in practice, mixtures of proteins of plant origin are not so effective in providing high protein quality in the ration as combinations of plant with animal or marine proteins

PROBLEMS

1 In the 1955 N R C Swine Standards the quantitative requirements of young pigs for essential amino acids are given Tabulate this list and compare it to the corresponding figures for the amino acid make-up of egg protein Are we justified in assuming the "egg distribution of essential amino acids is biologically ideal?
2 Compare with the swine requirement in the same way the amino acid make up of fish meal milk powder, soybean oilmeal, corn, and

oats Does this comparison give any qualitative suggestion as to desirable feed combinations for young pigs?

3 Compute the essential amino acid index (see page 86) for the No 1 swine ration shown in Table 8, p 16, of the 1955 N R C Swine Standard Plot the curve listing the amino acids in the same order as in the graph on page 87 What suggestions do you have for improving the biological value of the protein mixture of this ration?

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CHAPTER 5

Digestible Nutrients

WE HAVE DISCUSSED several terms and expressions which are commonly used in describing feedstuffs Some of these have been descriptions of the physical nature of the feed, some have been descriptions in chemical terms All of these descriptions have one feature in common, they are based on the assumption that if a feed has this or that nutritional characteristic the animal can make use of it We assume, for example, that because there is 15% of protein or 60% carbohydrate in a ration eaten that the animal has all of it to use Unfortunately, this assumption is not true In fact we must consider that ingested food is still outside the body until it has been absorbed through the wall of some part of the digestive system and has gotten into the circulating fluids of the body

The term *digestibility* is usually taken to imply that nutrients, or parent substances of nutrients, which are attacked by some digestive enzyme in the digestive system or are broken down by microflora, are absorbed Consequently, the term digestion as ordinarily employed implies both digestion and absorption, and we shall follow this concept in our discussions in this book

We can of course, go much further than mere digestibility and include some of the reactions in intermediary metabolism in describing nutritive properties of feeds, but for most cases information concerning the extent to which a nutrient in a feed is digested is of the greater practical value One reason why this information is so important is because differences in the digestibility of different feeds

to digestibility Dietary protein is attacked in the alimentary canal by digestive fluids and also by microorganisms Consequently, in addition to any undigested protein from the diet itself, the feces may contain protein of bacterial origin Furthermore, some previously digested and absorbed protein will have been metabolized into compounds that later are re-excreted into the digestive tract as digestive enzymes, some of which will be passed out of the body in the feces Thus, feces will contain nitrogenous material from three sources, i e, bacterial nitrogen, spent digestive fluid nitrogen, and undigested diet residue nitrogen There may also be small amounts of nitrogen coming from abraded intestinal mucosa, the amount of which is influenced by the quantity of dry matter consumed Except for that represented by the digestive fluids, the nitrogen that was absorbed will eventually be excreted via the urine Thus we see that apparent digestibility of protein (or of nitrogen) is not as accurately indicative of the extent to which the dietary protein was really digested, as with carbohydrate, but in practical feeding it is, nevertheless, an index of the extent to which the dietary protein is potentially useful

Dietary fat is perhaps in the same category as dietary protein, in that some of the fat of the feces may actually have been synthesized by bacteria and, thus, may erroneously be considered as a diet residue Some of the bacterial fat may have been synthesized from carbohydrate or protein rather than from diet fat itself However, since most animal diets contain only three or four per cent of fat, the error introduced is never large in terms of the total energy involved

We can understand therefore, that digestibility is not an equally useful descriptive term for all nutrients In fact, digestibility is not ordinarily determined at all for the mineral elements or for the vitamins Instead mineral balances are carried out in which all of the output is balanced against the total intake in an attempt to measure the fraction of the intake that is retained in the body Thus we find that coefficients of digestibility are ordinarily considered only for total dry matter, total energy, protein, fat, carbohydrate and its fractions of nitrogen free extract, cellulose, hemicellulose, or crude fiber

The coefficients of digestibility of the various organic fractions of

the proximate analysis have been determined for most of the commonly used feeding stuffs It is from such coefficients, together with the proximate analysis data, that we calculate the total digestible nutrients (TDN) of feeds

In practice, the coefficients of digestibility of these proximate principles and the calculated total digestible nutrients for feeds have been taken as constants and have, therefore, been used as a means of describing the feeding values in terms of available energy and digestible protein Feeding standards have been set up in which the requirements of animals are also described in these terms

The facts are, however, that digestion coefficients are not biological constants, and consequently total digestible nutrients values are not constants, and we must use such descriptive terms with a realization of their limitations if we are not to arrive at erroneous conclusions from them It will be desirable at this point, therefore, to consider some of the problems in the determination of the coefficients of digestibility in order that we may more fully realize their limitations

Technical Problems in the Determination of Coefficients of Apparent Digestibility

As we have already indicated, a measurement of the digestibility of a nutrient is essentially a bookkeeping job The *conventional* method of doing digestibility requires an accurate record of feed intake and of feces output From this information, together with a chemical analysis for the nutrient, the digestibility is actually calculated An example, in the case of protein, is given below

$$\%\ \text{digestibility of protein} = \frac{\left[\begin{matrix}\text{dry wt. of}\\ \text{diet eaten}\end{matrix} \times \begin{matrix}\%\ \text{protein*}\\ \text{in diet}\end{matrix}\right] - \left[\begin{matrix}\text{dry wt of}\\ \text{feces voided}\end{matrix} \times \begin{matrix}\%\ \text{protein}\\ \text{in feces}\end{matrix}\right]}{\text{dry wt of diet eaten} \times \%\ \text{protein in diet}} \times 100$$

Example Given the following data from a digestion trial

* Since protein is determined from a N analysis, the computations are ordinarily carried out with % N figures rather than the (N × 6.25) protein values

Amount feed eaten	100 gms
N in feed	3 %
Amount feces voided	25 gms
N in feces	2 %

$$\% \text{ Dig of N (or protein)} = \frac{[(100 \times 3\%) - (25 \times 2\%)] \times 100}{100 \times 3\%}$$

$$= \frac{(3 - 5) \times 100}{3} = \frac{250}{3}$$

$$= 83\ 3\%$$

The first real technical problem involved in the determination is to get a satisfactory measure of the feces belonging to the measured feed intake For the omnivora and carnivora the feces belonging to a given food intake are often identified by the use of markers Markers are usually colored substances that can be consumed as a part of the first meal of a digestion test and again as a part of the first meal after the conclusion of the test Their function is to color the feces subsequently produced from those feedings The animal is housed in a suitable stall or pen during the term of the trial and the feces are collected beginning with the first excretion that is colored by the first marker and continuing until the appearance of the second marker This quantity of feces is taken to represent the residue from the diet consumed from the first marked meal to the last unmarked meal, inclusive

Commonly used markers are iron oxide, bone black, and chrome green

The marker system for these species is reasonably satisfactory, as measured by the reproducibility of the digestibility coefficients in repeated tests However, we get some variation in results in such replicates, and a part of it is due to the fact that markers sometimes diffuse into adjacent unmarked meals, and, consequently, the separation of feces is not completely accurate The errors, however, are usually random and are minimized by using several animals and averaging the results

Marker methods are not satisfactory for use with herbivorous animals because the material from adjacent feedings is mixed, either in the rumen or in the caecum with the result that markers can give

no sharp division between feedings Markers are sometimes eliminated by cattle over a period of 4 days after having been fed at some particular feeding For herbivorous animals, therefore, experimenters have resorted to *time collections* for the determination of most of the digestion coefficients that are now published

The assumption we make in all digestion studies where we use time collections is that if a constant daily intake of a diet can be arranged over a sufficiently long period, the daily output of feces will also remain relatively constant, and that between fixed time intervals the feces collected represent quantitatively the output from the ration consumed over an equal period of time This assumption is valid only when time collection periods are of several days duration, in order that fluctuations from day to day may be balanced out Thus, whereas with marker methods we may have to continue the feeding of the test meal no longer than a week, we may have to continue the feeding for as much as three weeks in the case of cattle, in order to minimize errors in the estimation of the appropriate quantity of feces to be used in the digestibility calculations

Index Methods. We can avoid the need for quantitative collection of feces and quantitative records of feed intake in some cases by the use of index substances Index substances are materials that may be consumed by, or administered to, an animal, but that are entirely inert in the digestive system and are completely and regularly excreted uniformly mixed with the fecal material Where this method is used the digestibility is determined from differences in the concentration of the index substance in the feed and its concentration in the corresponding fecal output

Chromic oxide (Cr_2O_3) or chrome green is the most commonly used index substance at the present time Where the same combination of feed is fed at all feedings the chromic oxide may sometimes be mixed in fixed proportion with the batch as a means of getting it into the animal With rations made up of combinations of roughage and grain in differing proportions, or with diets in which the supplements and the basal feeds are fed separately, it is sometimes better to administer the index substance in a capsule The quantity to be

administered will depend on the amount of feed eaten, for the concentration of the index substance in the feed must remain constant over the test period

The calculations involved in the digestibility of protein where we use the index method is as follows

$$\%\ \text{digestibility of nitrogen (or protein)} = \frac{[(a \times \%N_1) - (b \times \%N_2)] \times 100}{(a \times \%N_1)}$$

Where a is the concentration of the index in the feed, and b its concentration in the feces, and N_1 and N_2 are the per cent of nitrogen in the feed and feces respectively

Example

In a 1 gram sample of feed carrying $3\% N_1$, 4 mg of Cr_2O_3 is found and in a 1 gram sample of feces analyzing $3\ 2\% N_2$ there is 16 mg Cr_2O_3 The digestibility of the protein is therefore

$$\frac{\left[\frac{1 \times 3\%}{4} - \frac{1 \times 3\ 2\%}{16}\right] \times 100}{\frac{1 \times 3\%}{4}} = \frac{\left[\frac{03}{4} - \frac{032}{16}\right] \times 100}{\frac{03}{4}}$$

$$= \frac{[0075 - 002] \times 100}{0075}$$

$$= 73\ 3\%$$

Quantitative Feed Records. There are also some problems in obtaining a quantitative record of feed intake Let us suppose, for example, that 100 units of some ration are offered to an animal that is to serve as a subject for a digestion trial For some reasons that may not be known this animal may consume 95 parts of this material and refuse the balance If it is dry matter for which we are determining the digestibility, there is no particular problem, for we can simply recover the uneaten feed, weigh it, subtract it from the total offered, and have a record of the dry substance that was actually consumed If however, we are attempting to determine the digestibility of some nutrient such as protein, then the problem may be complicated by the fact that the concentration of protein in the refused

portion of the feed may not be the same as the concentration of the protein in the part that was eaten Perhaps this problem also can be solved by recovering the uneaten feed, analyzing for nitrogen and calculating its probable protein, and deducting that from the protein of the total feed offered

Such correction of feed offered to take account of portions refused, may be satisfactory if we are merely concerned with the theoretical consideration of what a given intake of a nutrient actually does in terms of the response of an animal But if we are attempting to evaluate a food in terms of the usable nutrients it will furnish to an animal, we cannot disregard portions that are refused If these portions are consistently refused, because they are to all intent and purpose inedible portions, then a knowledge of the digestibility of a selected portion of the protein of the feed is of little practical use

Let us suppose that an allowance of corn stover or straw is offered to an animal, and varying quantities of it are refused To determine the digestibility of the portion eaten without regard to the uneaten portion gives a much higher valuation to the product than is warranted This is in effect what happens when the nutrients of refused feed are subtracted from the total offered in determining the digestibility Some investigators feel that the refused feed and the nutrients which it contains should be *added to the corresponding nutrients in the feces* This, in effect, charges against the value of the feed not only that which appears in the feces but that which is not edible

Indirect Digestibility. Thus far in our consideration of digestibility we have been concerned with problems where the feed in question constitutes the sole ration However, for most animals there are but relatively few feedstuffs that can constitute the entire ration for long enough to determine their digestibility When mixtures are fed there is no particular problem in determining how much of a nutrient came from one feed and how much from another It is not possible, however, to make any such separation in the case of the feces Consequently, it is not possible to measure directly the digestibility of a feed that is fed in combination with some other feed We must resort to *indirect methods*

To determine the digestibility of some feed or feed component by indirect procedures, two or more digestion trials are necessary In one of these the diet without the foodstuff in question is fed and the digestibility of its nutrients determined In a subsequent test the same diet (often referred to as the basal diet) is fed mixed with the food that is to be tested The total fecal output is measured as usual Then, on the assumption that the nutrient in the original basal diet shows the same percentage digestibility as it did in the first test when it constituted the whole of the diet, we estimate the amount of nutrient in the feces of the second digestion trial, presumably belonging to the basal portion of the ration The remaining fecal nutrient is considered to have come from the food being tested

Suppose, for example, we wish to test the dry matter digestibility of a dairy cow meal mixture It is not possible to feed a meal mixture as a sole diet to dairy cows, since without roughage they soon refuse food On the other hand, a roughage such as alfalfa meal can constitute the entire ration Consequently, we conduct our digestion trial with alfalfa as the basal feed Assume that in this particular case 40% of the dry matter consumed was recovered in the feces

Now we must conduct a second digestion trial, and in it we might feed 10 lbs of alfalfa plus 10 lbs of a meal mixture, from which a total of 5 lbs of dry feces is produced We now assume that from the 10 lbs of alfalfa eaten in this second test, 40% of it has reappeared in the feces, i e , that of the 5 lbs of feces produced in the second digestion trial 4 lbs of it came from the alfalfa The other one pound of fecal dry matter we consider to be a residue from the meal mixture The digestibility of the meal mixture would then be calculated as

$$\frac{10-1}{10} \times 100 = 90\%$$

The assumption in this procedure that mixing two foods together does not alter the digestibility of either one over that which it would have shown if fed alone is often unwarranted For example, with some poor quality roughage we may find that the digestibility of its dry matter is relatively poor Inasmuch as the digestibility of such

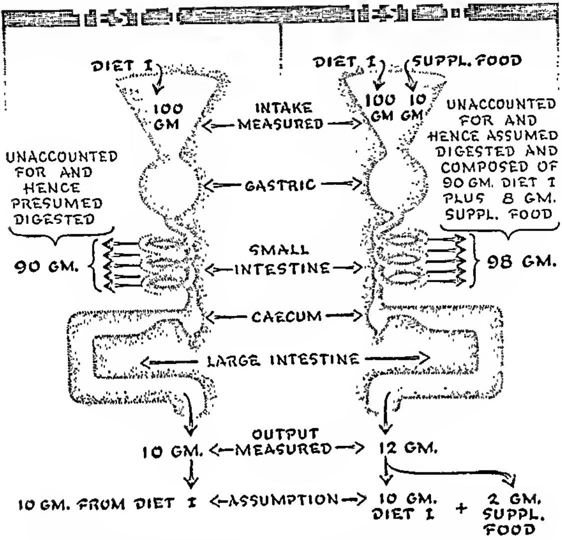

Fig. 5-1. *Schematic representation of the facts and assumptions involved in the calculation of the digestibility of a food.*

material is largely dependent on the activity of microflora which break down the cellulose and make the resulting fatty acids available to the animal, it is conceivable that a meal supplement, especially one that contains suitable food for bacteria, if fed with the roughage might result in a more complete digestibility of the cellulose portion of the poor roughage. *By the method of indirect digestibility any improvement in the digestibility of roughage would actually be credited to the meal supplement,* whereas in reality it may have been an improvement in the digestibility of the roughage itself which was involved. (Fig. 5-2 is an attempt to illustrate this situation.)

In this figure we assume that molasses as Food B added to some

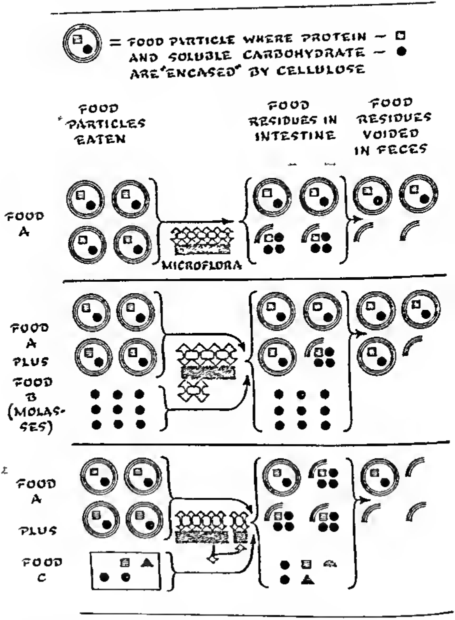

Fig 5 2 *Schematic representation of the hypothetical mechanism involved in the associative effect of foods*

Following ingestion microflora attack exposed cellulose and/or soluble carbohydrates Part of the cellulose thus becomes soluble in the sense that its end products are absorbable and yield energy The extent of the bacterial attack on cellulose may be conditioned

material called Food A may depress the digestibility by diverting bacteria from the job of breaking down cellulose, while the adding of Food C to Food A may actually increase the bacterial activity and hence increase the digestibility of Food A This interaction between foods is sometimes referred to as associative digestibility

The Arithmetic In actually working out the coefficient of digestibility of a feed that is fed in combination with some basal diet, we may understand the problem more easily if we remember that the coefficient determined for the combined diet, i e, the basal diet plus the supplemental food being tested, is actually the weighted mean of the digestion coefficients for the basal diet alone and the supplemental feed alone If these relationships are put into formula some interesting and significant facts may be shown

The general formula is

$$(B \times b) + (S \times s) = T \ (b + s)$$

where b and s are the proportions of basal and of supplement used in 100 parts of the mixed or total diet, and B S and T are the coefficients of digestibility for the basal diet, the supplement and for the mixture of the two respectively

By definition then

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by the nature of the other food which may divert or reduce the flora from such attack or in other cases stimulate it This action may reflect more a decrease or increase in total flora than a change in vigor of action

The end result may be an increase in the quantity of proteins soluble carbohydrate and unchanged cellulase in the feces (decreased digestion) as with Food B or the reverse as with Food C

There may be other causes of associative effects such as the conversion of dietary protein to bacterially synthesized carbohydrate or fat

The significance of such effects is that while in our example the alteration in digestibility is with Food A the change is actually charged against the second food whose digestibility is calculated indirectly and on the tacit assumption that the digestibility of Food A has not changed as a consequence of the addition of the other food Thus metabolizable values for such products may be erroneously high or low and in fact may be found variable depending on the diet in which they are used

$$b = (100 - s) \text{ and}$$
$$s = (100 - b)$$

The coefficient of digestibility of the supplement may then be shown as

$$\begin{aligned}(S \times s) &= -B\ (100 - s) + T\ (100)\\ &= -100\ B + Bs + 100\ T\\ &= 100\ (T - B + Bs)\\ S &= \frac{100\ (T - B)}{s} + B\end{aligned}$$

Thus, the digestibility of the supplement (S) is equal to the digestibility of the basal diet (B) plus the difference between the coefficients of digestibility for the basal diet (B) and that of the total mixed diet (T) divided by the proportion of supplement (s) involved

Let us suppose that by experiment the following values have been determined

$$T = 91\%$$
$$B = 90\%$$

with the mixed diet containing 20% of supplement

The digestibility of the supplement will then be obtained by solving the equation

$$\begin{aligned}S &= \frac{100\ (91 - 90)}{20} + 90\\ &= 95\%\end{aligned}$$

In cattle rations one must usually employ hay as the basal ration, in which case the coefficients for the hay (B) in the one trial, and for the hay plus meal (T) in the second trial might be

$$T = 60$$
$$B = 50$$

and let us assume that the proportion of meal was 40% of the total dry ration, then the digestibility of the meal mixture would be calculated as follows

$$\begin{aligned}S &- \frac{100\ (60 - 50)}{40} + 50\\ &= 75\%\end{aligned}$$

Effect of Variability

We have made no mention so far of the fact that comparable animals vary in their digestibility of identical rations. Some investigators believe that if coefficients of digestibility can be reproduced within five percentage units they are acceptably accurate. In experiments at Macdonald College variability in coefficients of digestibility of dry matter for four different species as measured by the standard deviation has been found as follows:

Species	Standard deviations of coefficients of digestion of dry matter
Human	± 0.93
Rat	± 0.85
Guinea pig	± 2.80
Swine	± 0.52
Sheep	± 1.33

The question to be answered is, how much difference must be observed between the digestibility of a basal diet (B) and that of the combination of basal plus supplement (T) before we can legitimately claim that the supplement (S) really differed at all from the basal diet in digestibility? This question can be answered from the standard deviation of the coefficients of digestibility. The standard deviation of a difference between two coefficients is equal to the standard deviation of a single coefficient times the square root of 2.

If we demand a probability of being right in 95% of the cases (odds of 19 to 1), we must approximately double this value. We can increase the accuracy of our figures by using several animals in each group to determine the digestibility figures. The final equation for the necessary difference between the digestibility of the total diet (T) and that of the basal diet (B) can be written as follows:

Necessary difference between

$$(T) \text{ and } (B) = \pm\left[\frac{S.D.}{\sqrt{n}} \times \sqrt{2} \times 2\right]$$

Assuming that we have 4 sheep in a group the numerical value for the necessary difference between T and B works out as follows

$$(T - B) = \pm \frac{1\ 33}{\sqrt{4}} \times 1\ 414 \times 2$$
$$= \pm 1\ 86$$

Thus, we see that for identical diets we shall have to expect digestion coefficients based on an average of 4 sheep per group to differ, by almost 2 percentage units, because of the operation of all of those factors that eventually lead to variation in digestibility If we now go back to our example of the 60-40 combination of hay and grain in which the digestibility of the basal diet (the hay) was 50%, and the digestibility of the mixture (T) was 60%, and using 4 sheep per group for the test, we can calculate how much the digestibility coefficient for the total ration fed must differ from that of the basal diet before we can claim there is any real difference between the supplement and the basal diet The calculation is as follows

Necessary difference between digestibility of the total ration (T) and that of basal ration (B) $= \dfrac{100\ (\pm 1\ 86)}{40} = \pm 4\ 7\%$

This calculation tells us that we might find in two replicate tests as much as $\pm 4\ 7$ percentage points difference in digestibility between *identical diets*

To go back again to our example in which a mixture of 40% meal and 60% roughage was fed we can interpret the digestibility of the supplement as follows

$$\text{Probable digestibility of } S = 100\ \frac{[(60 - 50) \pm 1\ 86]}{40} + 50$$
$$= 100\ \frac{(10 \pm 1\ 86)}{40} + 50$$
$$= \quad 70\ 3\% - 79\ 7\%$$

This, of course, is the same thing as saying that the probable ($P = 05$) digestibility of the supplement is 75% $\pm$ 4 7

It will be evident from the formulae presented above that the magnitude of the necessary difference between digestibility of supplement

and basal diet to cover random variability is much influenced both by the numbers of animals on which the mean digestibility coefficients are determined, and by the proportions of supplement used in the final diet fed Using the variation of digestion coefficients of dry matter for sheep again, we have calculated a series of values to show quantitatively these effects Those values are presented in Table 5-1

TABLE 5-1 *Fiducial Limits* (P = *05*) *Applicable to Mean Coefficients of Digestibility by Sheep of Feeds Determined Indirectly*

Proportion of supplement in ration fed	Number of sheep per group		
	1	5	10
10%	±37 6	16 9	11 9
20%	18 8	8 4	6 0
30%	12 5	5 6	4 0
40%	9 4	4 2	3 0
50%	7 5	3 4	2 4

The example case above in which the digestibility of a meal mixture is estimated by feeding first a basal diet of hay alone and subsequently a mixture of hay and meal, is reasonably clear-cut There are many cases, however, in which rather unexpected consequences of *the inherent variability of digestion coefficients come to light Let us* assume, for example, a pig ration in which the digestibility of the basal diet is 75% If, now, to this we add 5% of molasses, and feed this new mixture in order eventually to calculate the probable digestibility of the dry matter of molasses, and assuming that the *S D* of the dry matter digestibility coefficients for swine is ± 52, we discover that we cannot prove that the molasses differs in digestibility from the basal meal mixture The allowance which we must make above and below the digestibility of the dry matter of the meal mixture without the molasses turns out to be approximately 29 units of per cent, and 29 units of per cent plus 75% is more than 100% In other words, if we have only one pig on which to calculate the digest-

ibility we may expect to get differences in successive tests as great as ±29 percentage units between the molasses containing diet and the plain diet due to errors of the test alone If we can add 10% of molasses to the basal diet, then the allowance we must make is approximately 15 units of per cent, from which we would estimate that the digestibility of the molasses was not less than 90% If four pigs were available in each group, and we used 5% of molasses, we would have the same result as if we had used only one pig in a group and had 10% of molasses

These figures should make it clear that digestibility coefficients, and particularly those that we must determine indirectly, are not constants, and, consequently, that total digestible nutrient values also are not constants There is inherent in all such figures a certain minimum of variability, which we must recognize in any sound interpretation of values that involve their use

This, of course, does not mean that digestion coefficients and calculated digestible nutrient values are not useful in measuring feed values It does explain, however, why, under many conditions, the calculated TDN value for a feed or particularly for a ration, may lead us to expect certain performance of the animals that we fail to get A part of this failure is because the TDN values that appear in Feeding Standards are subject to the same uncertainties as are those for the rations that we prepare to meet these Standards, and it is not surprising, therefore, that all too often a ration that by calculation contains certain TDN values and certain digestible protein values still does not permit or encourage an animal to grow or to produce in accordance with expectations

Carbery's Method of Determining Digestibility

There is another method we can sometimes use to arrive at the probable digestibility of a supplement that is fed in conjunction with some other feed In this method it is necessary to conduct a series of at least three digestion trials in which in successive tests increasing proportions of the supplement to basal feed are involved If the supplement is of higher digestibility than the rest of the ration,

then by adding it to the ration the average digestibility of the total should be increased. And the rate at which this digestibility increases with increasing proportions of supplement is, in fact, the coefficient of digestibility we can credit to the supplement. We still must assume that the digestibility of the rest of the ration has not changed because of the supplement additions.

Data from such a series of trials can be plotted on a graph and

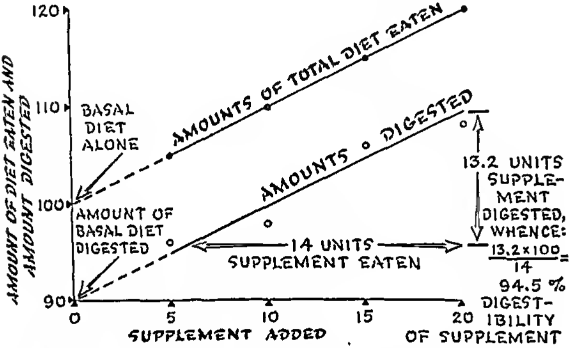


Fig. 5-3. *Carbery's method of calculating digestibility of supplementary feed in a ration.*

the digestibility of the supplement determined from the slope of the line best fitting the exerimentally determined points.

To set up this graph we use the ordinates to plot the total amounts of diet eaten and on the same scale the total amounts of the diet digested. Along the axis we lay off appropriate intervals in accordance with the quantities of supplement added to the basal diet. Fig. 5-3 depicts the results of a test in which to 100 units of basal diet there were added in successive trials 5, 10, 15, and finally 20 units of supplement.

Thus, there are points on the graph corresponding to the intersection of 5 and 105; 10 and 110; 15 and 115; and 20 and 120 units

of feed eaten These points of intersection are connected and if extrapolated to the 0 supplement ordinate it should cut it at the 100 units mark We now plot a second set of points on the same graph representing the average amount of the rations digested Assume these points to be 96, 99, 106, and 108 for the four levels of supplement The best fitting straight line representing these four points is now drawn and this is extrapolated also to the 0 supplement ordinate In the example case this regression cuts the 0 ordinate at 90, which means that when no supplement is added to the basal diet we can predict its digestibility to be 90% (i e , 90 out of 100 consumed) If we measure the slope of this regression line connecting the points for the amounts digested at the four different trials, we find that for 15 2 units of supplement, 14 2 were digested The per cent of digestibility of supplement is, therefore (14 2 – 15 2) × 100 = 92 5% This method helps to find the most probable digestibility of a supplement, since the regression indicates the trend with due regard to the variability of the individual tests The method becomes more precise as we increase the number of different basal-supplement mixtures tested, since this gives more points from which to establish the regression line Its chief limitation is the requirement that several digestion trials shall be conducted with varying proportions of the same supplement and basal diet This procedure becomes costly and time consuming However, where the supplement and the basal diet are closely alike in digestibility such a series of tests may be a valuable scheme for obtaining a reasonable estimate of the digestibility of the supplement

Coefficients of Apparent Digestibility and the Proximate Analysis

Schneider* has examined critically the sources of variability in digestibility data and has shown that the apparent digestibility of a feed is influenced by the proximate analysis His finding means that feeds of the same name, but which differ in chemical make-up, will show differing digestibilities This fact would be particularly impor-

* *J Animal Sci* V 9 p 373 (1950)

tant in the case of forages where chemical composition changes radically with the stage of maturity, although the feed is still called by the one name It will also be important in feeds where in the milling process the chemical composition may be altered Thus, there are different protein levels in the cottonseed meals Furthermore, there are marked differences in chemical composition of cereal grains The protein content of barley, for example, runs all the way from 9% to about 19%, and other grains show similar magnitude of variability in this nutrient Any change in the composition as to protein must be reflected in a change in the composition of one or more of the other proximate principles

Schneider* has shown that somewhere between 30 and 50% of the total variability in the digestibility of differing samples of the same feed can be traced to one or another, or to a combination of the proximate principles

For animal feedstuffs he has worked out values to be used in regression equations for predicting the digestibility from their proximate analysis The equation in simple form is as follows

$$Y = C + bx_1 + b\ x_2 + b_3x_3 + b_4x_4$$

In this equation C is a constant that is specific for the nutrient and the class of feed under consideration The b's are the partial regression coefficients, and the x's the moisture-free percentages of protein, crude fiber, nitrogen free extract and ether extract respectively for *the sample of feed for which it is desired to estimate the digestibility* from the proximate analysis The b values for a considerable number of feeds have been worked out by Schneider and can be found in his paper published in the *Journal of Animal Science*, V 11 1, February, 1952

An example of the application of this equation is as follows.

Given a feed analyzing

Protein	6 5%
Crude fiber	34 2%
N-free extract	47 4%
Ether extract	2 1%

* *J Animal Sci* V 9, p 504 (1950)

Taking the equation above and substituting in it the values for b and for x as given in Schneider's table, we find the digestibility estimated as

$$Y = 215\ 8 - (2\ 489 \times 6\ 5) - (2\ 820 \times 34\ 2) - (\ 891 \times 47\ 4)$$
$$= 61\ 9\%$$

The extent to which the differences in chemical composition may affect the apparent digestibility are indicated in the case of two samples of linseed oilmeal, the one carrying 35% protein and the other 32 6% Using the appropriate constants from Schneider's tables again, we find that the 35% protein linseed oilmeal would be estimated at 78 3% digestibility, while the protein of the other would be 86 3%

This calculation is but another way of saying that with equal dry matter intake, increases in the concentration of protein (i e, increases in the per cent of protein in the ration) are not matched by equivalent fecal protein output This effect is exaggerated by the fact that the amount of metabolic fecal protein is related to the amount of dry matter eaten, but not to the level of protein The situation may be illustrated by data from a rat test,* in which a highly digested protein was fed in varying levels Thus, the fecal N was almost entirely metabolic and bacterial The intake-output relations are shown in Fig 5 4, and Table 5 2

The result of the situation shown is that the fecal output becomes a smaller and smaller fraction of the intake as intake increases, and hence the per cent apparently digested increases with the per cent of protein in the ration

In comparison, studies with pig rations, showed that natural fiber depresses digestibility of protein more than protein level increases it, and thus rations of increasing protein and decreasing fiber will show a different effect on protein digestion from combinations in which increases of fiber are associated with decreases in protein concentration

It should be clear that descriptions of feeds in terms of the digestibility of their nutrients' can be given only in general terms Average

* Crampton and Rutherford *J Nut* V 54, p 445 (1954)

TABLE 5-2 *Apparent Digestibility of Protein and Per Cent of Protein in Diet Combinations*

Basal diets	Supplement* 0 Basal diet 100		Supplement 20 Basal diet 80		Supplement 40 Basal diet 60		Supplement 60 Basal diet 40		Supplement 80 Basal diet 20		Supplement 100 Basal diet 0	
	Cheese	Egg	Cheese	Egg	Cheese	Egg	Cheese	Egg	Cheese	Egg	Cheese	Egg
Shredded wheat	13**	11	17	18	22	26	26	33	32	40	36	—
100%	80†	79	82	83	86	86	88	89	88	91	90	—
Shredded wheat	10	9	15	15	20	24	25	31	31	39	36	42
80% plus												
Methocel 20%	73	68	80	79	85	86	87	87	89	90	90	94
Shredded wheat	8	7	13	14	18	22	24	30	30	38	36	47
60% plus												
Methocel 40%	71	64	80	79	84	85	86	87	88	91	89	94

* Cheese or egg

** % protein.

† Apparent digestibility of protein.

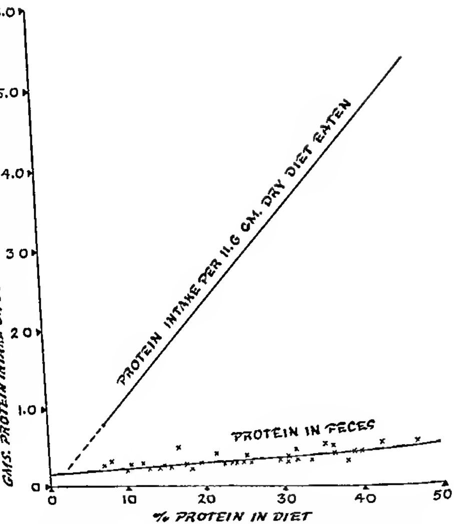


Fig. 5-4. *Daily protein intake and feces protein at varying dietary protein levels*

values will be useful but cannot be taken as constant characteristics applicable to all samples

PROBLEMS

1 Tabulate from the data in *Feeds of the World* (Schneider) the TDN values for corn, barley, oats, wheat in such a way as to compare the differences in the figures, both in the case of cattle and of swine, according to whether the feed constituted the entire ration (direct determination) or was fed along with another feed and the digestibility therefore determined "indirectly." How well do these figures compare within species?

2 What proportion of the feeds given in the appendix tables of this book could be fed as the entire ration to cattle, to growing pigs?

3 Do you think typical or average TDN values should be relied on to predict the useful energy values of feed mixtures intended for livestock feeding? Be careful—the answer here will require thought

SUGGESTED READING

Cipolloni, Mary Ann, et al, "The Significance of the Differences in Digestibility of Feeds by Cattle and by Sheep," *J Animal Sci*, V 10, No 3, p 337 (1951)

Crampton, E W. and Rutherford, B E, "Apparent Digestibility of Dietary Protein as a Function of Protein Level," *J Nut*, V 54, p 445 (1954)

Schneider, B H and Lucas, H L, "The Magnitude of Certain Sources of Variability in Digestibility Data," *J Animal Sci*, V 9, p 504 (1950)

Schneider, B H, et al, "The Value of Average Digestibility Data," *J Animal Sci*, V. 9, p 373 (1950).

SUMMARY OF SECTION I

Now BEFORE leaving this section, let us recapitulate some of the terms that we have been discussing The important ones are listed below

Name Classification Moisture Protein Total, Digestible, Quality—Biological Value, Replacement Value, Chemical Score, Essential Amino Acid Index Ether Extract, Total, Digestible Ash, Total, Calcium, Phosphorus, Toxic Elements

Carbohydrate Crude Fiber, Cellulose, Hemicellulose, Lignin, Digestibility Nitrogen-free Extract, Total, Digestible Available Energy Total Digestible Nutrients, Starch Equivalents, Digestible Calories, Metabolizable Energy, Net Energy

Are you not surprised at the number of terms or items which are used in trying to describe the nutritive properties of feedstuffs? Feedstuffs are complex combinations of nutrients In the compilation of tables of feeds, the N R C Committee on Feed Composition is recording about 70 items, including amino acids, mineral elements, and vitamins, as well as the fractions of the proximate analysis and a selected group of carbohydrates

More important, of course, than a mere knowledge of the different descriptive terms used, is familiarity with the precise meaning and the limitations of these terms Through carelessness, and sometimes from slipshod thinking, we can be led into misuse and/or misinterpretation of some of these terms, the end result of which may be failure to employ the feed in such a way that its full value is obtained, or

any adverse effect of its defects avoided. For example, the fallacy of the common assumption that TDN is a constant for a given feed is clearly evident when one looks critically at the nature of this term. Many nutritionists feel that rations are often inefficient because of faulty or inadequate descriptions of the properties of the individual feeds quite as much as because of ignorance of the requirements of the animal. Nowhere is a faulty premise likely to lead to an unexpected result more surely than in the problem of ration formulation. A faulty assumption as to the nutritive properties of a feed or ration may be the whole explanation for an unpredicted and usually undesirable performance of the animals fed.

The significance of full and accurate descriptions of feedstuffs will be increasingly evident as we proceed, first with a consideration of the nutrient needs of animals; then to a study of feedstuffs themselves; and finally take up the problems of compounding feed combinations of specified nutritive properties. Actually at this point we are closing only our formal examination of the nature of the terms used in describing feedstuffs; we begin now to use them to understand the subject matter that lies ahead.

SECTION II

NUTRITIONAL REQUIREMENTS OF ANIMALS

Obviously, before we can make any useful start on the actual formulation of rations, we msut have a reasonably clear working knowledge of what nutrients such rations must contain From one point of view this may be even more necessary than precise understanding of the physiological roles these substances may play in metabolism

The information should be quantitative, at least with respect to those nutrients that constitute any significant proportions by weight of the ration And right here the problems begin How accurate must our "quantitative' data be in order to prepare nutritionally adequate and, at the same time, economically sound combinations

Investigators and practical livestock men have for many years recorded what they have observed to be the quantities of nutrients needed by animals Others have sought similar answers by calculation from the data of metabolism studies For those needs that have been longest studied (such as energy and protein) the figures now available are workably accurate in the sense that rations devised from natural feedstuffs to provide these quantities permit normal performance by the animals subsisting on them For many, indeed for most of the

specific operating needs, there are no finalizing figures that can be called requirements

This lack of definite figures must mean first, that many, and perhaps most, "natural' feeds contain quantities of the nutrients needed for the maintenance of livestock including requirements for some, though perhaps not optimal growth, production, and reproduction, and secondly, that if the overall needs are reasonably well met by adequate allowances of such foods the animal can adjust itself to widely differing intakes of specific nutrients

And so it is not really surprising that the results of our search for more accurate and complete data relative to the nutrient requirements of livestock has not been so much to change the general specifications of animal rations as it has to increase the scope of feeding standards to include facts about nutrients previously unknown Thus the performance of modern rations in the feed lot is more predictable, because the unknowns are fewer, more efficient, because the balance of nutrients is more satisfactory and more economical, because previously unrecognized surpluses are more completely eliminated

Quite apart from the greatly expanded scope of the modern feeding standard over its earlier prototype, a fundamental fact of nutrition has emerged from our more complete knowledge it is that in applied feeding the basic need of animals fed normal rations is for energy, and that this demand is the basis of most, and perhaps all of the other nutrient requirements

It seemed logical, therefore, in a consideration of animal requirements, and before examining the detail of actual feeding standards, to establish thoroughly the basis for, and the present evidence concerning the energy needs of livestock Then, because protein has so often (though erroneously) been taken to be the nutrient of greatest practical significance in successful livestock feeding, we should examine critically the present position of this nutrient in the formation of rations We shall then mention briefly the minerals and vitamins necessary to augment the data of feeding standards

Finally we shall discuss the characteristics of livestock feeding standards and present for examination those for dairy and beef cattle, and for swine

CHAPTER 6

The Energy Requirements of Animals

NO ONE can feed experimental animals or be associated with the practical feeding of commercial herds without soon realizing that the performance of the stock is critically linked with the quantities of feed individual animals consumed daily. The buyer of "feeder" cattle scans the animals for characteristics believed to indicate good feeding ability. Judging score cards have emphasized broad muzzles, deep hearts, and blocky conformation with the implication that these indicate good feeding ability. Horsemen, sheepmen, and hogmen have also stressed feeding ability as an important characteristic in desirable animals.

There is justification for this emphasis on feed intake in relation to performance. Production by livestock, whether it is of milk, or wool, or of body tissues, requires energy in excess of maintenance; and feed intake is almost synonymous with energy intake. The most common nutritional cause of poor performance of livestock is that of too meager intake of feed. Many nutrients are required because of their function in energy metabolism, and others that appear to be needed in proportion to body size are, therefore, indirectly required in proportion to feed consumption. Since natural feeds not only yield energy to the animal but also carry assortments of specific nutrients, increasing feed intake often automatically corrects other deficiencies that may have appeared under too meager feed consumption.

The factors that regulate, or at least affect the willingness of ani-

mals to eat and influence the extent of their consumption are by no means fully understood Perhaps the one most certainly known fact is that the taste of the feed is seldom the major important factor, *though there are some exceptions* Bitter weed seeds, for instance, or musty or dusty materials are often refused by animals Aroma may sometimes be a factor because of the stimulating effect it has on early gastric secretions in simple stomached animals Some tastes may also be acquired, and ration changes may, therefore, cause temporary food refusal

The more important problem, however, is related not so much to complete feed refusal as it is to the unwillingness of animals to "eat their fill" Why does voluntary feed intake increase when an unsatisfactory quality of the protein component is corrected either by feed substitution or by amino acid amendment to the ration? Why does feed intake decline when animals are on restricted water intake? These are not problems of taste or smell, and they are not solved by the inclusion of condiments or flavoring substances

It is an attractive hypothesis that the body's defense mechanism against further ingestion of substances that disturb its normal metabolism is to decrease feed intake In any case, deficiency of essential nutrients, perhaps excesses of certain nutrients, or the accidental ingestion of enzyme poisons, such as fluorine, often show their first adverse effects in precarious appetite and lowered feed intake

That adequate feed or energy intake is necessary for normal performance is an accepted fact Under self feeding, the problem scarcely exists (assuming a satisfactory ration), but for those animals to which regulated quantities of food are offered at each feeding it becomes important to know how much is enough' The answer is not always indicated by appetite In a milking herd consumption must be adjusted to production for reasons of economy, and in the production of bacon carcasses the energy need of the bacon pig differs from that of the fat hog at certain stages of growth

Hence, in view of its special importance we should deal at this point in some detail with the fundamental basis of the quantitative energy requirement of animals This may be the more pertinent since feeding standards usually present little if any of the biological back-

ground underlying the requirements we have to consider in a discussion of energy requirements

The Maintenance Energy Requirement of Adult Animals

Although the metabolism of energy-yielding nutrients in the body is not a direct oxidation as in a furnace, the body, nevertheless, uses oxygen in proportion to the rate of its metabolism By simultaneously measuring the heat escaping from the body and the oxygen consumption of that animal over the same period of time, we can establish a caloric equivalent of each liter of oxygen This calculation has been made for many species and under many conditions, and within relatively small error (less than 3%) we can assume that for each liter of oxygen consumed the body will lose 4 825 Calories of heat as a result of metabolism In order to maintain an animal in energy equilibrium this quantity of energy in the form of food must be replaced to the body Using suitable equipment to measure oxygen consumption we can then compute the amount of energy an animal requires to maintain energy equilibrium under conditions that may be defined

Basal metabolism represents the irreducible energy cost of maintenance of an animal during rest in a thermo neutral environment and in a post-absorptive state To maintain an animal in energy equilibrium under practical everyday conditions the ration must contain, in addition to this minimum for basal metabolism, increments sufficient to cover any additional caloric needs occasioned by expenditures for activity and/or production, to allow for fecal and urinary losses, and to balance the energy wastage incidental to food utilization

To be useful in applied feeding, energy requirements must be stated in terms of rations Consequently, the caloric equivalent of the above categories must be evaluated as well as the basal metabolism, and their total expressed in some appropriate term

Basal Energy Metabolism. We refer to the minimum energy cost of the automatic body processes representing the excess of endo-

thermic over exothermic reactions as basal metabolism Energy used in circulation, excretion, secretion and respiration accounts for perhaps 25% of this cost—the balance being required for maintaining muscle tone and body temperature

Basal metabolism has been measured for animals of many different sizes, and from such data have come two facts the basal heat production is affected by the weight of the animal, and the metabolism of small animals is greater than that of large animals per unit of body weight

Theoretical considerations suggest that basal metabolism might be related to the surface area of the body If the heat losses were affected by radiation, surface might be a factor, and the ⅔ power of body weight (i e , $W^{2/3}$ or $W^{.66}$) is a better index of surface than is weight to the first power (i e , $W^{1.0}$) However, we must note that exterior body surface is not a constant in living animals, nor can it be measured satisfactorily Furthermore, the casual factors of the heat production, and hence of the basal heat loss, are not dependent on external body surface Consequently, we may conclude that the relation between surface area and basal metabolism is not a direct expression of cause and effect Rather, we should consider that W^n is a measure of physiological effective body size, or metabolic size, and that the value of the exponent, *n*, should be determined from the data in question

The relationships may be expressed mathematically as

$$C = b\,W^n$$

or

$$\log C = \log b + \log W^n$$

If C is Cals basal metabolism and W^n is metabolic size, then the ratio of $\frac{C}{W^n}$ should be a statistical constant, b

Basal metabolism data for adult animals of species ranging from mice to elephants were plotted by Brody* on log, log paper and the regression fitted by the method of least squares The slope of the curve proved to be 0 73, and the value of b, the ratio of $\frac{C}{W^{.73}}$ was

* *Bioenergetics and Growth* (1945)

70.5. Thus the data indicated that, on the average, Cals. basal metabolism = 70.5 ($W^{0.73}$). The numerical value of b depends on the units of measurement used. When metabolism is in Calories for 24 hours and weight is in kilograms, $b = 70.5$; when weight is in pounds, $b = 39.5$.

Brody states "The direct control of the metabolic curve resides not in the external surface but in the neuro-endocrine system, which (for geometric and mechanical reasons discussed in his text) tends to vary in size with surface area rather than with simple body weight. So it comes about that the size of the neuro-endocrine components, the surfaces, the heat dissipation, and the heat production all tend to vary in parallel. They may all be said to vary with W^n, and the value of n tends to be near 0.7. It will be shown presently that the quantity of milk-energy production and of egg-energy production likewise tends to vary with $W^{0.7}$, as does basal energy metabolism and endogenous protein metabolism. This brings out the broad significance of the proposed reference base $W^{0.7}$, which may be termed "physiological" weight in contrast to $W^{1.0}$, which is the "physical" or gravitational weight. In the meantime, it is suggested that $W^{0.7}$ be tentatively adopted as reference base for basal-energy metabolism, endogenous nitrogen excretion, milk-energy production, egg-energy production and related processes."

Note that both Brody and Kleiber now recommend that the equation be written:

$$\text{Cals. basal metabolism} = 70(W_{\text{kg}}^{.75})$$

and consider it to be a biologic constant applicable to all homiotherms.

It may help at this point to review the energy categories with which we deal in animal feeding. Fig. 6-1 is an attempt to show these categories in their proper relations.

From the chart in Fig. 6-1 we can see clearly that we have in basal metabolism the starting point for calculating either the metabolizable, the digestible, or the total energy that must be returned to the animal as food. The basal metabolism value depends on the biologic size of the animal. The increments to be added to this value

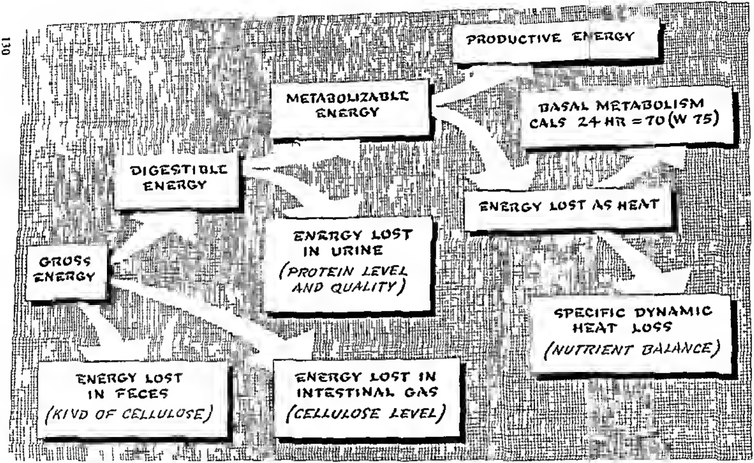


Fig 6 1 *Energy categories in nutrition* (*The chief factors determining magnitude of the loss are given in parentheses*)

depend on, (1) the nutritional balance of the ration, (2) the activity and/or production of the animal, (3) the protein level of the ration, (4) the nature and extent of the cellulose or crude fiber of the ration, and (5) the energy of the fecal excretion.

Specific Dynamic Heat Loss. We refer to this energy category under a variety of terms including *specific dynamic action* (SDA), *heat increment of feeding, thermal energy,* etc. The biological origin of the energy category has been variously assigned. That it represents the work of digestion has been disproved by feeding a variety of foods in the digestion of which no SDA was found, as well as by the fact that amino acids made available to the body for metabolism by injection give rise to the same quantity of SDA as when they are consumed normally. There is evidence to suggest that it represents a decrease in the efficiency of energy metabolism of food eaten as compared to that occurring under basal conditions. This conclusion is supported by the observation that the proportions of energy-yielding nutrients in the ration influence the SDA. For example, absence of an essential amino acid results in an increase in SDA. This may be explained on the hypothesis that under such a situation the normal synthesis of protein is hampered; and, consequently, a larger quota of amino acids must be deaminized. The disposal of such amino acids may be less efficient in terms of energy expenditure than is protein synthesis, and since the body must remain at constant temperature there is an increase in the heat loss.

This effect is not limited to energy-yielding nutrients. The lack of common salt in the ration reduces the utilization of the metabolizable energy of corn by increasing the heat loss from the body. Limitation of phosphorus causes similar effects. Thus possibly SDA is a reflection of the degree to which the ration eaten fails exactly to meet the nutrient needs of the body at that time.

Whatever the specific cause, the fact remains that the heating effect of feeding is large and, to a considerable degree, unpredictable. For cattle Fig. 6-2 illustrates the average utilization of energy of a typical ration fed at maintenance level.

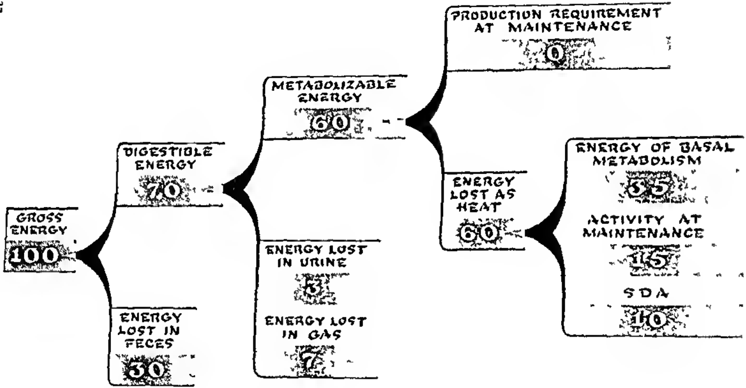


Fig. 6-2. *Approximate partition of ration energy by cattle at maintenance intake.*

These figures (Fig. 6-2) are Brody's analysis of data available in 1934 except for the partition of the heat loss category. The figures for SDA represents the average for the SDA of cattle rations at maintenance levels; and that for activity is calculated from the energy of basal metabolism. According to Mitchell, the activity of animals at maintenance increases basal requirements by 25-50%.

Of all of these figures, that for SDA is the most variable, ranging from 3 to about 20% of the gross energy of the feed as the plane of nutrition increases from half to three times maintenance.

Energy Lost as Gas. The extent of the gas losses will depend largely on the quality and quantity of cellulose fed. As the proportion of roughage in the total ration decreases (as from a maintenance all-roughage ration to a milking ration containing only two-thirds or less of its dry weight as roughage), the gas loss also decreases.

In the usual digestion trial the gas loss is counted as a digestible nutrient since it is not in the feces. Consequently, the apparent digestible energy of a high roughage ration is over-estimated by usual figures for either TDN or for digestible energy. This error will be discussed in more detail at a later point.

Fecal Energy Losses. With omnivora, because of the nature of their usual foods, the utilization of ration eoergy is appreciably higher than with herbivora. Digestibility for one thing approaches 85%, and gas losses are lower; hence we may find that the sum of the basal metabolism plus the "activity" energy requirement at maintenance is about 75% of the gross ration calorie requirement. The activity at maintenance for the smaller species is very likely relatively higher than for the larger animals. Mitchell places the "activity of idleness" of small animals at double that of the larger species.

We may reasonably assume that the total heat loss by adult swine at maintenaoce living is 70% of the total energy and may be partitioned as basal metabolism 45%, activity plus SDA 25% of the gross energy needed; for cattle the corresponding values may be more nearly 60%, 35%, and 25%.

From Feeding S/ ...

Calculation of Adult Maintenance Energy Requirement. Practical adult maintenance energy requirements of animals generally may be calculated from the formula

$$\text{Cals} = a \times b \ (W^{n})$$

where W^{n} is "metabolic size of animals," i.e., body weight in kilograms raised to the 0.75 power, $b = 70$, the Cals. required per unit of metabolic size for resting metabolism, and a, the factor to convert the "resting" caloric requirement to that for maintenance. We may think of it as an "activity factor" covering the energy cost of the incidental activity of non-producing adult animals being maintained in constant body weight.

The numerical value of factor a will vary, depending on whether the requirement is to represent metabolizable energy or digestible energy. In the first instance it includes the energy cost of incidental activity and the specific dynamic heat (energy) loss of maintenance levels of food intake. Where it represents digestible energy the value of a will be larger, since it must include the average urinary losses of energy from protein metabolism, and the digestive tract (energy) losses of fermentation gases from carbohydrate (cellulose). The latter loss is importantly involved only in herbivora and, consequently, the factor a varies also with species of animal. In other words, the terms of our equation are constants only in the sense that they hold for average conditions. It has been estimated that the caloric requirement calculated by this formula will carry with it an error expressed as a coefficient of variation of about $\pm 7\%$ of the mean. That is, that the probable true maintenance energy needs of an individual animal will in two cases out of three be within $\pm 7\%$ of this calculated average caloric figure.

The suggested value of a in our equation to calculate digestible calories is 2 for herbivores and 1.4 for omnivores.

If we desire finally to obtain the requirement in terms of TDN we must divide the calorie figure by the caloric value of TDN. Here we must choose between a figure of 4.00 and of 4.38 Cals. per gram, as has already been discussed. Use of the latter value will probably give a figure for digestible calories more nearly in line with the true

requirement; but if the *ration* TDN is calculated on the usual basis, the feeding standard allowance for the animal will not be adequate, since the present way of determining TDN over-estimates the available energy of the ration by about 10%.

Summary of Maintenance Energy Requirements of Dairy Cattle from Feeding Standards. Since 1810 when Thaer's* Table of Hay Equivalents was published, feeding standards of one sort or another have appeared periodically. Most of them were applicable to dairy cattle, where feeding according to need was of greater economic importance than it was with stock whose production was the gain in body size or where maintenance of weight was the only criterion needed. Some of these tables received wide acceptance while others were short-lived. Many are of historical interest, and the evolution of feeding standards, as indicated by the features of the better known ones of each era, is a record that parallels the advancement of scientific feeding of livestock. The early standards dealt largely with energy requirements, though this was not specifically expressed and perhaps not at the time recognized. True, these tables, after about 1850, included a figure for protein as well, but in the light of present knowledge, essential information given about protein was meager.

The record as to the total energy needed by a given animal, regardless of the particular terms in which it was actually stated has been surprisingly constant. The calculations from a few of such standards are summarized in Table 6-1.

The calculated TDN values equivalent to the original terms of Table 6-1 are approximations only, since conversion from calories to TDN is subject to considerable error. However, they illustrate a situation that is of interest and perhaps of significance: that, generally speaking, the maintenance energy requirement given in standards where it was determined on the basis of *energy balance,* is about 20% lower than in standards where the estimates have come from *feeding trials* with the TDN needed to maintain body weight calculated from the amount of rations eaten and their TDN content.

It is worth noting, however, that Morrison in his latest standard

* *Landwirtschaft*, p. 211 (1880).

TABLE 6-1 *Daily Energy Requirements for the Maintenance of Adult Dairy Cattle (Calculated to a live weight of 1000 lbs and converted to the equivalent TDN values)*

Feeding standard		Original terms	Approximate equivalent TDN (1)*	Approximate equivalent TDN (2)†
			lbs.	lbs
1909	Kellner	2.631 kg starch equivalent	6.8	6.2
1917	Armsby	6 therms net energy	6.5	5.8
1931	Forbes and Kriss	8.487 therms metabolizable energy	5.8	5.2
1935	Brody	2 × 70.0 (Wt .75) Calories	6.8	6.1
		Average	6.5	5.8
1903	Haecker	7 lbs. Dig Carbohydrate + 0.1 lb Dig fat + 0.7 lb dig protein	7.9	7.1
1912	Savage	7.925 lbs TDN	7.9	7.1
1915, 1936, 1950	Morrison	7.925 lbs., 7.925 lbs., 7.00–7.93 lbs TDN	7.9	7.1
1950	U.S. Research Council	8.00 lbs TDN	8.0	7.2
		Average	7.9	7.1
		General Average	7.2	6.5

* Based on 1000 Cals. equivalent to approximately 250 gm TDN
† Based on 1000 Cals. equivalent to approximately 228 gm TDN.

gives a minimum "recommended" allowance that is some 10% below his previous figures. This reduced value together with the statement from the Committee responsible for the U.S. National Research Council Standard, that its allowance is liberal, because underfeeding is the most common cause of unsatisfactory dairy cow performance, leads to the conclusion that the most probable daily requirement for the energy maintenance of an average 1000 lb adult dairy cow is not far from 6.5 lbs TDN or very nearly 12 therms of digestible energy. In equation form we may write it

$$\text{lbs TDN} = \frac{1.72 \times 70(W^{.75})}{1816}$$

We should recall that the energy requirement forms the basis of the requirement of many of the other operating needs of the body. It is, therefore, essential that this figure be established with as little error as possible. *Using as a standard an intake that is in excess of true requirement may lead to difficulties from unexpected sources.* In practical feeding a single meal mixture is prepared for all animals of the same feeding category, and allotments are made to individuals. All nutrients are thus in fixed proportion to the total feed, which is essentially the same as saying they are in fixed proportion to the energy of the feed.

If, for example, in preparing a mixture, one were to use a standard for energy that actually called for an excess of 20% in energy, while that for protein was the true requirement, then a cow on being fed enough to keep her in constant weight would receive too meager an allowance of protein. Intentionally liberal estimates of *nutrient* requirements are thus less serious than is the use of a larger than necessary figure for *energy*.

How Much Feed? It may be necessary to consider the *amounts* of food needed to supply specified quantities of digestible energy. The reason for considering this matter at this point stems from the way in which tables of nutrient requirements are actually used in applied feeding. The data comprising a feeding standard are primarily useful as guides to the formulation of meal mixtures from which animals of the same feeding category will be offered appropriate quantities. The formulation is seldom an inflexible recipe. It changes as frequently and as rapidly as ingredient availability and price fluctuate.

Examination of formulae recommended by various agencies reveals a surprising uniformity (sometimes by geographic area) in the calculated TDN content of meal mixtures intended for any one feeding category (such as milking cows, nursing sows, laying hens, etc.). The reasons for this are more deep-seated than the simple fact that the between-mixture differences in TDN might be expected to be smaller than that between single feeds. At the moment it will suffice to state that pattern meal mixtures intended for milking cows, as well as

typical feed combinations designed for most feeding classes of swine, carry very close to 75% TDN when they are based on corn, and about 70% when the basal feeds are largely barley or oats

Thus, it is feasible to express finally the daily energy requirements of animals (whether for maintenance or for producing stock) in terms of equivalent pounds of feed, and specifically in terms of a quantity of meal mixture, after suitable adjustments are made for feeds other than meal that are used (as in the case of herbivores)

The general equation may be written

$$\frac{\text{lbs air dry meal}}{\text{required per day}} = \frac{a \times 70\ (W^{.75})}{1816 \times \%\ \text{TDN in feed to be used}}$$

The figure 1816 assumes 4 Cals per gram TDN If the value of *4 38 Cals is preferred, the figure 1938 should be used The per cent* of TDN should correspond in the feeds involved

The significance of a separate statement of the maintenance energy requirement varies with the class of stock involved Idle adult farm animals are normally fed maintenance rations but in many instances the ration consists of roughage alone, and is fed essentially *ad libitum* If the animals do not maintain their weight, supplementary concentrate feeds may be given For swine the meal allowance is restricted to a quantity that maintains live weight Feeding standards for energy are seldom used under these conditions

Where producing cattle are to be fed it is possible and, with dairy cattle, customary to arrive at the final feed requirement by adding together the maintenance and the product needs In practice the producing stock (other than dairy cattle) is sometimes grouped by weight, age, and/or production category and the total requirement stated as one figure Thus pregnant heifers and pregnant mature beef cows are separately grouped, each by live weight But lactation allowances are given separately Similarly, young and adult pregnant swine and young and adult nursing sows are separately listed

The fundamental basis of the maintenance energy needs for all adult stock is the same and the feeder who has a working knowledge of the principles involved will be able to make sound adjustments in feed allocations to individual animals

Energy Cost of Production and/or Work

The energy cost of muscular activity as in work, and that for the production of milk or wool, or the synthesis of body fat, must also be taken into account in the feeding of livestock. We should call attention to the fact that excepting for adult breeding cattle, the maintenance needs of animals are not in practice dealt with as separate values. Rather, the maintenance needs are combined with those for production into one figure. Nevertheless, we should look into the energy requirements of milk production and of fat production in order to appreciate how differing rates of production eventually affect the total feed allowances.

The partition of the digestible calorie intake between maintenance, milk production, and body gain in weight cannot be made directly. However, Brody and Proctor have attempted to obtain an estimate of this partition by using the statistical device of partial regression. They have assumed for this purpose that TDN is used for three purposes in the body, viz., maintenance, body gain, milk production. The basic equation to indicate the relationships might be written as:

$$\text{TDN consumed} = b_1\ (x_1 - \bar{x}_1) + b_2\ (x_2 - \bar{x}_2) + b_3\ (x_3 - \bar{x}_3)$$

where

x_1 = lbs. 4% milk produced per lactation
x_2 = average metabolic body weight (i.e., $W^{.75}$) during lactation
x_3 = change in body weight during the lactation
b_1, b_2, b_3 are the units of TDN required for each unit of x_1, x_2, x_3, respectively.

Brody and Proctor have applied this method to 243 yearly lactation records of Holstein and Jersey cows in the Missouri Agricultural Experiment Station from which they derived the following figures:

$$\text{TDN} = 0.305\ (x_1) + 0.053\ (x_2) + 2.1\ (x_3).$$

Assuming 1816 Cals. per lb. TDN, we may calculate that for each pound of milk of 4% fat content produced requires (.305 × 1816 =

553) cals Since a pound of 4% milk contains 340 Cals, the net efficiency of production is (340 ÷ 553 = 61) 61%, or to produce milk requires, in addition to maintenance of the cow, 1 61 times the energy contained in her milk (Experiments have shown that efficiency of production is independent of body size)

Forbes and Kriss of the Pennsylvania State Agricultural Experiment Station have estimated from their data that the energy cost of milk production is 1 67 times the metabolizable energy consumption, which agrees satisfactorily with Brody's value based on TDN

Estimated Cost of Body Fat Production. Kriss has reported that the efficiency of metabolizable energy for body weight increase in adult cattle is 59%, which, if expressed in terms of digestible energy, might be taken as approximately 50% ($\frac{85}{100} \times 59 = 50$), if we assume that metabolizable energy is 85% of digestible energy with cattle On this basis, double the calories deposited as body fat would be required in the ration in excess of the maintenance energy

Energy Cost of Work. The energy cost of work (muscular activity) is considerable As measured by rate of oxygen consumption it has been found that the energy cost of standing above lying is about 9% in man, cattle, and sheep The horse does not show any increased energy need in this respect because of the special anatomical arrangement of his suspensory ligaments However, walking results in an increase in energy expenditure of about 100% over standing, and that figure seems to hold true for several species Sustained work shows energy expenditures in relation to the energy requirement at rest, something as follows

Activity	Ratio of O_2 consumption of activity to that of standing
Walking	2
Sustained heavy work (6 10 hr per day)	3 8
Maximum activity per day	20
Maximum energy during maximum brief effort	100

In horses, an average expenditure can be worked out on the assumption that the normal load is 10% of the body weight and that the speed is about 2.2 miles per hour. The figures in terms of TDN are computed by Brody according to the formula:

TDN per day = 0.053 ($W_{lb}^{.75}$) + 1.27 × (Horse power per hour). The daily requirement thus calculated according to the size of the horse and the hours worked per day, are shown in Table 6-2.

TABLE 6.2 *Pounds TDN Required for Maintenance and for Work According to Total Hours Worked per 24 Hours*

Hours working (out of 24)	Weight of horse (lbs.)		
	1000	1400	1800
	lbs.	lbs.	lbs.
0 (maintenance)	8	10	13
2-4	2	3	4
5-8	5	7	9
9-12	8	11	15

The exact values for a given animal are subject to wide variation, as might be expected since it is obvious that many factors other than body weight, weight of load, and rate of movement are involved. Thus far no simple classification has been devised to describe severity of work, which we can use as the basis of estimating energy requirements. The problem may be more academic than practical, because the criterion in actual feeding is maintenance of body weight (see thumb rules later). The ordinary plan of allowing quantities necessary for maintenance of weight is satisfactory if we take the precautions to adjust day by day the allowances to correspond to marked changes in activity (as on idle days). Table 6-2, however, may give some idea of the quantities that would be involved.

Energy Requirements of Growth

Sometimes we can express the energy needs of adult animals, in two separately measurable quantities: one for maintenance, and an-

other for specific activity involved in addition to maintenance With growing animals overall increase in weight is continuously variable, and in practice one must not only feed to maintain the weight and size attained, but provide enough more to permit further gain in weight

The increase in weight of animal normally follows a characteristic pattern related to age, which, in turn, may reflect changes in nutrient needs Hence, so-called normal growth curves are often used as indices of requirements of growing animals We should, therefore, consider briefly the normal growth of animals

The Nature of Growth. While the overall change in body weight with advancing age can be represented as a smooth curve, the different tissues do not individually grow with equal rapidity For example, muscles increase 48 times in size from birth to maturity, while the skeleton only makes a little more than half this change Curves of skeletal growth, therefore, when plotted against age, are flatter than curves of total weight gain Hammond,* in his studies of the effect of age and nutrition on change in body proportions, found that the body proportions of fat type pigs of 100 lbs weight were essentially the same as those of bacon-type pigs of 200 lbs liveweight

Of particular interest is the effect of plane of nutrition on development at different stages of maturity Pigs, following weaning, held on meager rations for 16 weeks, and then full fed to a slaughter weight of 200 lbs showed relatively poor muscle development and heavy layers of external fat Others fed liberally following weaning and then, beginning at 16 weeks, given restricted intake showed the greatest development of lean tissues and the least fat when killed at 200 lbs The growth curves (age-weight graphs) of the pigs from these two regimens were strikingly different That for the low high' nutritional program showed a continuously increasing upward trend, that for the high low regimen was sigmoid, showing a steadily accelerating slope to 16 weeks followed by a segment of less rapid weight gain

* *J Agr Sci* V 5 (1937)

Measures of Growth. At the outset we may state that body weight alone cannot be an accurate measure of tissue growth. An animal may remain at constant body weight while simultaneously losing water or fat, but growing in skeleton. In practical livestock husbandry a combination of body weight plus a measurement such as height is often of greater use as a guide to feed allowances than either alone. Thus, standards of normal weight-for-height-for age make it possible to distinguish between well-grown individuals and those that are heavy because of excessive fat deposition. Such a standard for two breeds of dairy cattle is already in use. Some of the figures are shown in Table 6-3, and plotted in Chart 6-A. These data can be plotted for use with intermediate values.

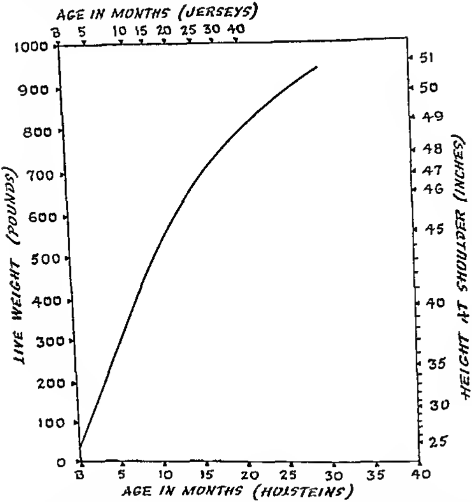
TABLE 6-3 *Weight-Height-Age Relations in Normally Grown Dairy Heifers*

		Age	
Weight	Height at withers	Jersey	Holstein
lbs.	inches	months	months
100	28.5	1.0	.5
200	34.0	6 0	3.0
300	38.0	7.5	5.0
400	41.0	9.0	7.0
500	43.5	12.5	8.0
600	46.0	18.0	12.0
700	47.5	26.0	16.0
800	49.0	40.0	20.0

The importance of the problem of accurately measuring true growth varies with species and cases. For animals being raised for breeding herds the desirability of a more accurate assessment of nutritional needs than is necessary for short-lived "meat" animals, will perhaps justify the more elaborate schemes.

The General Nature of Growth Curves. If we record the live weight of an animal periodically from birth to maturity, plot these

CHART 6-A. *Graph of Age, Weight, Height Relationship in Dairy Heifer Calves*



weights against time at relatively short intervals, and join the points on the graph, we get a curve depicting the trend of 'growth' If we thus measure a sufficient number of comparable animals the line representing the average weights for age will be a smooth curve of sigmoid form The curve will have two major segments The first is of increasing slope and extends from birth to puberty The second is of decreasing slope and runs from puberty to maturity The point of inflection, which coincides with puberty in most species, is of

biological significance in that it marks a point of physiological age equivalence between species. At this age rate of potential growth is at a maximum, as is also feed efficiency as measured by feed required per unit of body increase.

Puberty occurs with most animal species when they have attained about one-third of their mature size. The normal curves of animals beyond puberty coincide if plotted on a physiologically equivalent age basis.

Problems in the Use of Growth Curves. Much research has been undertaken to establish normal growth curves, and relevant data have been published for most species of animals. In nutrition such curves are used primarily as standards against which to gauge the adequacy of nutrient allowances. In fact, so-called normal growth curves are often the entire basis for the allowances set down in dietary and feeding standards.

Obviously if rates of growth are in part hereditary, discrepancies in attained body size between growing animals of identical ages will increase with advancing age. Consequently, any classification for growing animals will include a relatively wide range of weights at any specified age, and a growth curve based on averages at advancing ages will not necessarily depict satisfactorily the expected normal growth of individuals.

One must bear in mind also that because daily gain in body weight is the most often used criterion of nutritional adequacy of growing animals, it does not follow that maximum gain is the desired objective. Indeed, rapid gain may be an index of a faulty nutritional regimen as is so well illustrated by Hammond's studies on the relation of plane of nutrition and age on body proportions. A rapid gain on market pigs after a weight of about 100 lbs. indicates rapid fattening, which may be damaging to bacon carcass quality.

Energy Requirements for Growing Animals

Gains in weight by growing animals in accordance with some normal growth standard is the most commonly used criterion of

adequate feed intake Feed intake is almost synonymous with energy intake, since unless feeds differ markedly in fat content, they are of quite similar gross energy, and for any one species of animal the types of feeds used in the ration are enough alike so that differences in digestibility of the dry matter of typical rations are not wide

To determine energy requirements on the basis of the growth of animals, we conduct a bio assay type of feeding trial Comparable groups of animals are fed different amounts of a ration, the digestible energy content of which is known The intake of energy by animals that grow at rates comparable to those of the normal growth curve is taken as the energy requirement

To arrive at a feeding standard by this method is time consuming and costly It is necessary to observe many different groups in order to obtain values not biased by the hereditary characteristics of any one group or strain of individuals

Mitchell has suggested a somewhat different approach to the problem of establishing the energy needs of young animals in which he considers that total energy requirement may be partitioned into a maintenance fraction an activity fraction, and a new tissue fraction He cites the data for a chicken given in Table 6-4

TABLE 6-4 *Calculations of Caloric Requirement of a Growing Cockerel (Mitchell)*

Weight of bird	Basal Metabolism	Activity 50% of B.M	Tissue formed	Total Calories
lbs	Cals	Cals	Cals	Cals.
0.5	37	18	15	70
1 0	55	27	19	101
2 0	72	36	21	129
3 0	94	47	19	160

In his scheme the energy requirement for maintenance is actually the basal metabolism plus 25 or 50%, the smaller value for larger types of animals and the larger for smaller species The "growth" requirement is the caloric value of the new tissue formed as de-

termined by slaughter tests and analysis of tissues. Of critical importance is the magnitude of the activity factor, data for which are limited at present.

Mitchell's plan in reality treats true growth as a "production" (in excess of maintenance). His treatment is entirely logical from the standpoint of nutrient needs, and has the theoretical advantage of making possible the use of already well-established methods for calculating the maintenance requirements on the basis of the attained size of the animal and the relation which this bears to basal metabolic rate.

Efficiency of Energy Utilization by Growing Animals. In general, the energy stored in the successive equal weight increments becomes larger with advancing age because of the change toward lower water and higher fat content of body tissues with increasing age. Thus with advancing age more energy intake is needed per unit of body gain. This increased feed cost of gain is strikingly seen in the case of the market pig that for the whole of his life is "growing."

Age of pig	Gain in body weight per 100 lbs. feed
Months	Lbs.
2-3	40-50
3-4	25-30
4-6	18-20

Such figures are subject to a considerable modification with rate of gain of animal. In slower gaining animals, where a tissue of relatively low fat content is being formed, the gain per pound of feed will be appreciably higher with animals that are rapidly fattening. From feeding standards that indicate both the expected feed intake and the expected weight increase, we can calculate the expected feed efficiency as feed required per unit of gain.

This figure may be useful in judging the adequacy of the nutrient combinations represented by the feed mixtures fed. If the animals are eating less than the standard calls for, as might be in the case of intentional feed restriction, we might expect that their gains would also be restricted. If the gain–feed ration remains "normal" one

TABLE 6-5 *Feed Requirements for Growing Cattle According to Live Weight Attained*

Normal live weight	Expected daily gain (lbs.)			Total air dry feed (lbs.)		Daily feed requirement (lbs.)			
						Grain (75% TDN)		Roughage (50% TDN)	
	Small breeds (dairy)	Large breeds (dairy)	Beef breeds	Dairy	Beef	Dairy	Beef	Dairy	Beef
50	0.5	0.5		1		1		0	
100	1.0	0.8		2		2		0	
150	1.3	1.4		4		4		0	
200	1.4	1.6		6		4		2	
400	1.2	1.8	1.6	11	12	4.5	3.5	7	8.5
600	0.8	1.4	1.4	15	16	4	1.5	11	14.5
800	1.1	1.2	1.2	19	19	2.5	0	17	19
1000	—	1.3	1.0	22	21	0	0	22	21
1200	—	1.2		24		0		24	

TABLE 6-6 *Feed Requirements of Growing Pigs According to Live Weight Attained and Type of Carcass Wanted*

Normal live weight	Expected daily gains		Average daily feed		% TDN of meal	
	Fat type	Bacon type	Fat type	Bacon type	Fat type	Bacon type
lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs
5 25	60	.60	2.0	2.0	80	80
25 50	65	65	2.6	2.6	75	75
50 75	1.25	1.25	3.6	3.6	75	75
75 100	1.35	1.35	4.7	4.7	75	75
100 125	1.45	1.45	5.6	5.6	75	75
125 150	1.60	1.50	6.5	7.0	78	67
150 200	1.70	1.55	7.3	8.0	78	67

could assume that the nutrient assortment met requirements. If low feed intake is a voluntary reaction by the animal, then faulty nutrient assortment may be the cause of the restriction. In such cases, however, feed efficiency is usually also adversely affected.

Normal Growth Curves, Daily Feed Intake, and Expected Daily Gains of Young Animals. From the previous discussion we can see that any average statement of the energy requirements of young animals will be but a rough guide to the needs of specific individuals or of small groups of comparable animals. It may be useful, however, to record typical data that are in use by the livestock feeder—data against which he frequently checks his own results.

In order to set a workable figure for the daily feed that growing animals may be expected to consume corresponding to their live weights, we have to indicate as well the energy value of the rations referred to, particularly for herbivorous animals where, with advancing maturity, the ration normally changes from one of relatively high TDN to one including more roughage material.

Growth data and suggested corresponding feed requirements for young cattle and swine are shown in Tables 6-5 and 6-6.

Conclusions: Where Do We Stand Now?

In the preparation of a modern feeding standard the figure we finally set down for any particular category of animal as its probable daily need for energy, whether it be expressed as calories or TDN or starch equivalent, we must base on such considerations as those presented in the foregoing pages of this chapter, together with a review of the data from comparative feeding trials designed to elucidate energy needs. The discussions here, of necessity, have been abbreviated and the factors often simplified. Nevertheless, we should now understand that any decision on the probable true energy needs is not a simple matter of averaging figures. Perhaps some will conclude that the whole matter is a hopeless jumble—that we can find no solution at present. Such a conclusion is a defeatist attitude and is unjustified in the light of the record of steady progress in ration efficiency, which parallels the development of feeding standards.

The fact that the problem is complicated illustrates forcefully one of the so often disregarded characteristics of all feeding standards—that the figures are guides to the probable needs of a hypothetical average animal of the particular feeding category in question, but

they are not to be taken as defining in any precise way the quantity of a diet component that will need to be supplied to a specific animal for its optimum performance Indeed, there may be no such figure, the needs of an individual may vary almost continuously for causes either not detectable clinically or not recognized as related to the problem

This possibility in no way defeats the purpose of the feeding standards nor minimizes the need for critical evaluation of data on which they are based In practical feeding, we can make adjustments when desirable to meet the peculiar needs of individual animals within feeding standard categories by adjustments in total feed allowances

These adjustments are left to the pig or the beef critter or the sheep wherever self-feeding is practiced With the dairy cow and the horse regulation of the concentrate feeds allows the feeder to use his skill in feeding, but even here different but comparable animals consume differing quantities of forage, and thus are not likely to consume identical quantities of nutrients

But to establish the *proportions* of nutrients generally best suited for a feeding group, we have to set down average or at least typical values for each nutrient When viewed in this light the significance of feeding standards is at once apparent

PROBLEM

1 Using the formulae on pages 136, 137, and the figure for net efficiency of milk production (p 140), prepare a table giving the TDN and the pounds of meal needed by milking cows of weights of 900 1100 and 1300 lbs that are fed roughage of 50% TDN at rates of 2 lbs per 100 lbs body weight, and are producing 4% milk in daily amounts of 25 40, and 55 lbs How does your feeding standard compare with that of N R C ?

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CHAPTER 7

Requirements for Protein

FUNDAMENTALLY, it does not seem logical to attempt to rank on the basis of importance the nutrients animals require If they are requirements, they must all be present, and the consequences of deficiencies are undesirable From the standpoint of practical feeding, however, and especially in the sense of daily requirements, we can rank nutrients in the order of their importance Thus, we find that deficiencies of energy cause prompt and usually economically important modifications in the performance of the animal Reactions to unfavorable protein levels are almost as prompt Appreciable deficiencies in total protein or in the quality of protein, are reflected in decreased voluntary food intake and in less efficient use of the food that is eaten Marked surpluses in protein over optimum requirements also reduce the efficiency of the ration through increasing the specific dynamic heat loss from the body

Most of the mineral elements, and most of the vitamins, are accumulated in the body, from which sources they are available for varying lengths of time to carry on their nutritional functions Consequently, deficiencies of such materials frequently do not result immediately in altered response by the animal But with protein, storage appears to be limited, and, consequently, the losses of protein from the body must be made good continuously through dietary intake

Because adjustment of the protein level of the ration is normally arranged by selection of appropriate feedstuffs, and because the quantities required bear a close relationship to the energy require-

ments, we need to discuss the fundamental basis of protein requirements in some detail. The quantities of protein presumed to be needed daily by animals of various feeding categories are specifically set down in current feeding standards. Such standards, however, do not discuss the problems underlying the determination of the requirements or the factors that may modify requirements, an understanding of which may be useful in getting the most out of our feedstuffs.

We should point out at the outset that in the minds of many livestock feeders lack of enough protein is the cause of most of the unsatisfactory results of livestock feeding. This attitude has undoubtedly arisen, in part, from the emphasis placed on "balanced rations" at a time when balance was considered to be primarily a matter of proportion of protein to carbohydrate equivalent. In practical livestock feeding undoubtedly many cases of unsatisfactory performance of livestock have been improved by more liberal allowances of foods of high protein content. It was quite natural, then, to ascribe such beneficial effects to protein; but recent evidence shows clearly that the improvement was frequently due to other nutrients that were contained in high protein feeds. It is also worth pointing out that in many cases the use of high protein feeds actually increased the available energy of the mixture through replacing low protein feeds of high fiber, or for other reasons of low available energy content. For example, the introduction of linseed oilmeal into rations as a partial replacement for oats not only raises the protein level of the mixture but also reduces the fiber content and increases the TDN of such a mixture.

Fate of Dietary Protein

The basis for the requirement of protein in the ration eventually traces back to the losses the body suffers in nitrogenous end-products. In order to maintain the animal in nitrogen (or protein) equilibrium the intake must be sufficient to balance the output loss. It may be helpful, therefore, to consider the fate of the protein ingested by an animal in its ration. Fig. 7-1 is a flow-sheet diagram marking the different channels through which this nutrient finally disappears from the body.

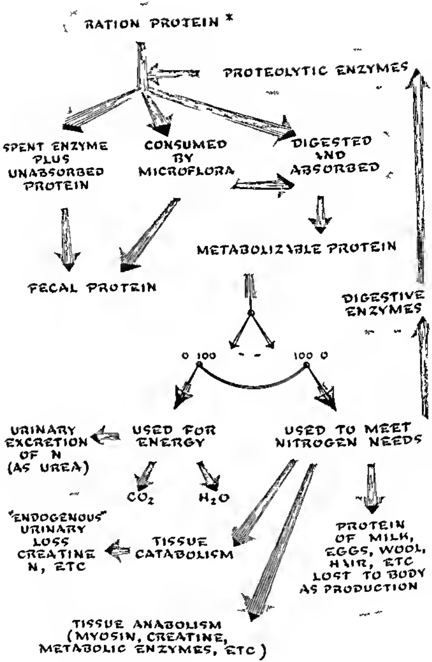

Fig 7 1 *Protein metabolism flow sheet*

Referring to Fig 7-1, we should note that the losses of this nutrient from the body of an adult non-producing animal may be grouped into four categories.

1) Undigested and hence unabsorbed diet protein residues,
2) Nitrogenous residues from the intestinal microflora,
3) Spent digestive fluid nitrogen,
4) Urinary excretion of the nitrogen wastage from the catabolic phase of intermediary protein metabolism

For animals that are storing protein, such as in growth, there will also be requirements for tissue anabolism, and if animals are producing protein-containing products such as eggs, milk, wool, hair, etc , there will be a further requirement to meet these needs

To maintain an animal in protein equilibrium obviously these losses must be replaced Their sum represents the protein requirement of that animal To arrive at a working figure for the sum, we have to consider at least the more important factors that influence the losses represented

The nitrogen (or the protein equivalent of that nitrogen) of the first three categories above appears in the feces undifferentiated as to origin The nitrogen of two of these categories does not represent undigested protein of the diet They are, rather, the chief components of what is referred to as metabolic fecal nitrogen In applied livestock feeding the question of the exact origin of these two fractions, or even of the total quantities of protein they represent, is of relatively minor importance Of much greater significance is the relation they bear to the protein intake requirement

By definition the apparent digestibility of protein is the percentage of the intake that is not recovered in the resulting fecal excretion To the extent that any portion of the fecal protein is not an unabsorbed diet residue, the calculated apparent digestibility of protein will be smaller than the true digestibility Because of the technical difficulties in measuring true digestibility, associated actually with the measurement of the metabolic fecal nitrogen, and because of the fact that the metabolic losses must ultimately be made good by protein intake

in any case, it is universally customary to use the apparent digestibility coefficient in dealing with applied feeding

This practice, however, introduces a problem frequently overlooked in considering the protein value of feeds and, consequently, in dealing with statements of protein needs The factors involved may be summarized somewhat as follows Protein from spent digestive fluids is proportional to the total feed intake and is independent of level

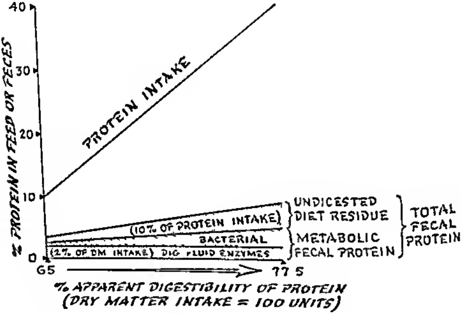

Fig 7 2 *Relation between protein intake and its apparent digestibility (Dry matter intake constant)*

of protein intake Bacterial protein of the feces probably increases slightly with increasing protein intake, since there may be some increase in the total microflora in liberal protein consumption The undigested diet protein residue should be a constant fraction of the protein intake for any given ration if we assume that the quantity of protein does not affect its true digestibility The consequence is that apparent digestibility of the protein of a food is in part a function of the per cent of protein it carries This is illustrated in Fig 7-2

Thus, we see that where no other factors are involved, the higher the per cent of protein in the ration the higher its apparent digestibility is likely to be There are, however, other factors involved among which crude fiber is perhaps the most important Increases in crude fiber in the ration tend to depress the digestibility of the protein Consequently, if increases in protein level are accompanied by increases in crude fiber as well, we may find little change in apparent digestibility since the increasing protein is balanced by increasing fiber insofar as the effect on apparent digestibility of the protein is concerned If, however, by increasing the protein level the crude fiber of the ration is simultaneously decreased, then the effect of increasing the concentration of protein will result in an increase in apparent digestibility of the protein Schneider made a quantitative study of the relationships between the proximate principles of a feed and the apparent digestibility of the several components using the statistical device of multiple correlation and regression He has published the following general equation for predicting apparent digestibility of protein of a feed, from its protein (X_1), fiber (X_2) and nitrogen-free extract (X_3) content

$$\% \text{ digestibility} = C + b_1X_1 + b_2X_2 + b_3X_3$$

Values for C and for the partial regressions (b) are specific for the class of feed and the appropriate figures are given in his paper * Only three of the four proximate principles are used in any one case

The effect of level of protein on its digestibility is illustrated by the calculations for two feeds of differing (i e, 35% vs 12%) protein level

$$\begin{aligned}\text{Feed A, Dig} &= 4\,7 + 1\,233(35) + 755(8) + 626(52)\\ &= 86\,4\%\\ \text{Feed B, Dig} &= 62 + 821(12) + 1\,20(8) + [-204(77)]\\ &= 65\,7\%\end{aligned}$$

From one point of view this question of apparent digestibility of protein is academic, since the range of protein levels ordinarily sup

* *J Animal Sci* V 2, p 1 (1953)

plied in the final mixed rations of livestock is not great enough to distort the apparent digestibility sufficiently to affect adversely the preparation of rations

Referring again to the flow sheet, we can see that the protein that is eventually digested and absorbed may be entirely used to meet the protein needs of the body, or it may under some circumstances be very largely used for energy, and the amino groups excreted in some form in the urine The proportion of the digested protein that is actually used to meet protein needs in the body is called the biological value of the protein Two major factors appear to regulate the biological value of the protein of the diet The first one is the level of energy nutrition If the energy requirements of the animal are not fully met by non protein sources, then enough of the digested protein will be diverted to meet the energy deficiency

When the energy requirement is adequately supplied from non protein sources, the chief factor that will control the proportion of the digested protein used for protein needs will be the particular amino acid assemblage of that protein As the proportions of amino acids approach the ideal the biological value will increase

Biological values of proteins, however, are not constants, they will be higher under minimum intake than when liberal allowances are fed This variation is partly because there is an upper limit to the needs at a given time, and surpluses of ideal mixtures of amino acids will be no more useful than left-overs from poor assortments Furthermore, the assortment needed is not constant but depends on the tissue to be synthesized We find clear example of this in the amino acid make-up of wool as compared to that of skeletal muscle (see Table 7-1)

Marston suggests that the make up of the amino acid pool available to the tissues in the circulating fluids determines, in part, not only the total but the kind of tissue that will be formed in the body Thus wool growth can be favored by arranging for relatively higher intakes of the sulfur-containing amino acids

We can see that the proportion of the digested and absorbed protein from the ration, which ultimately is used to meet the nitrogen

TABLE 7-1 *Amino Acid Composition of the Protein of Diet, Wool, and Muscle*

	% of amino acid N in total N in		
Amino Acid	Diet protein	Wool protein	Muscle protein
Cystine	1.2	9.0	0.8
*Methionine	1.4	0.4	1.9
*Threonine	3.4	4.7	3.9
Arginine	12.5	20.0	15.3
*Histidine	2.8	1.1	4.1
*Lysine	5.2	3.2	10.4
*Tryptophane	1.5	0.6	1.0
*Phenylalanine	2.6	1.9	2.6
Tyrosine	2.4	2.0	1.5
*Leucine	6.2	7.2	5.3
Isoleucine	3.1	—	4.2
*Valine	4.1	3.4	4.3

* Essential amino acids

losses from the body's metabolism, is a variable and is determined largely in an otherwise adequately nourished animal by the quality of the ration protein in terms of its amino acid make-up. For the moment it makes little difference whether there is a "pool" of amino acids, to which catabolic residues and dietary intake contribute, and from which quotas may be drawn for anabolism as needed, or whether some other scheme actually operates to permit the continual synthesis of enzymes and other nitrogen containing molecules indispensable for body function. The fact is that under an energy adequate nitrogen-free dietary regime with adult non-producing animals of all species we find an irreducible minimum daily urinary nitrogen excretion, which represents a steady loss of protein to the body from its metabolism. To attain nitrogen equilibrium this loss must be replaced from dietary sources.

In this connection we must interpret "dietary sources" somewhat liberally in order to include the herbivorous group of animals whose

bodies obtain the necessary assortment of amino acids indirectly from the diet through the synthesis of proteins by the intestinal microflora, so that the feeder of herbivorous animals does not need to arrange his ration to contain all of the essential amino acids He must, however, supply about the equivalent of these amino acids in total protein in order to provide the necessary nourishment for the microflora found in the digestive tract

Quantitative Considerations. Quantitatively this minimum protein metabolism of adult animals, as represented by the minimum endogenous urinary nitrogen output, is related to their metabolic size This relation is evident from the fact that there is at all body weights a practically constant ratio between basal metabolism and so-called endogenous urinary nitrogen These represent, respectively, minimum energy and minimum protein expenditure Brody has assembled data showing this ratio (see Table 7-2)

TABLE 7-2 *Basal Metabolism and Endogenous Urinary Nitrogen at Different Body Weights*

Body weight kgm	Basal metabolism Cals/kgm	Endogenous urinary nitrogen mg/kgm	Ratio N_{mg}/Cals
1	70.5	146.0	2.07
10	38.2	76.6	2.00
20	31.8	63.0	1.98
40	26.5	52.0	1.96
80	22.0	42.7	1.94
100	20.7	40.2	1.94
500	13.5	25.6	1.90
All weights	223.2	446.1	2.0

The resting energy metabolism, as we have already seen (Chapter 6), is expressed by the equation

$$\text{Cals} = 70(W_{kg}^{.75})$$

Realizing that the endogenous urinary nitrogen is expressed in milligrams, we can from the data of Table 7-2 write an equation for the probable minimum protein requirement in pounds as follows:

$$\text{Minimum protein}_{\text{lbs.}} = \frac{2 \times 70 \times (W_{\text{kg.}}{}^{.75}) \times 6.25}{1000 \times 454}$$

Examination of the appropriate data from the literature led Brody to conclude that the regression of "endogenous urinary nitrogen" on metabolic body size was 146 mgs., which agrees well enough with the value of $(70 \times 2) = 140$ mgs. calculated from the ratios of Table 7-2. This value, 146 mgs. or 140 mgs., converted to its protein equivalent and expressed as pounds, would represent the maintenance requirement of animals for digestible protein if all of that which was digested were used to meet body protein requirements. That is to say, the protein had a biological value of 100%.

The effective biological value of ration proteins, or even the digested portion of them, is much below this figure. There does not appear to be any way of predicting what the actual biological value of a dietary protein will be; and even if there were, it seems unlikely that practical feeding practice would be adjusted with enough precision to take advantage of such information. For economic reasons, substitutions of feeds are frequently made at the expense of some quality in the protein mixture. What we really need is a working biological value that will be applicable to a protein mixture found in a typical balanced ration and fed according to acceptable practice.

One way of estimating this wastage due to imperfect biological value might be by comparing the digestible protein allowance that feeding standards give for the maintenance requirements with the basic minimum protein figure as indicated by our calculations above. When we do this for cattle we find that the "minimum" requirement is about one-quarter of the digestible crude protein figure representing the average of the more important feeding standards in use today. Specifically, the calculations indicate that if the minimum protein requirement calculated from the formula given above is multiplied by 3.4, the resulting figure agrees with the average digestible protein requirement for the maintenance of 1000 lb. dairy cows according to current feeding standards. The calculations are shown below:

$$\left.\begin{array}{l}\text{Lb D.C.P. equivalent of}\\ \text{24 hrs. endogenous uri-}\\ \text{nary nitrogen per 1000}\\ \text{lb. cow}\end{array}\right\} = \frac{146\ (456^{.75}) \times 6.25}{454 \times 1000} = 0.198 \text{ lb.}$$

$$\left.\begin{array}{l}\text{Av. D.C.P. for main-}\\ \text{tenance for 1000 lb. cow}\\ \text{(from feeding standards)}\end{array}\right\} = 0.67 \text{ lb.}$$

Ratio Total/Endogenous $= 3.4$

Let us speculate as to how we make up this 3.4 figure. Obviously we must include the wastage due to imperfect biological value, and some workers in protein nutrition have suggested that probably on the average the effective biological value of animal ration protein is not far from 50%. If we should take this figure we would have to double the calculated minimum endogenous protein equivalent calculated from our original formula. The other losses will, for the most part, be associated with metabolic fecal protein losses, and it has been estimated that under minimum conditions these in total are about equal to the endogenous urinary nitrogen excretion. However, there is no very satisfactory way of arriving at a reliable figure here, and perhaps the best we can do is to determine our result by difference. For what suggestive information they may give, some of these relationships have been worked out in Table 7-3.

TABLE 7-3 *The Maintenance Requirement for Protein by a 1000 lb. Adult Cow*

Category	Determined as	D.C.P. lb.	Multiple of endogenous
Endogenous urinary loss	$\frac{146\,(W^{.75}) \times 6.25}{454 \times 1000}$	.198	1
Allowance for Biological Value of only 50%	equal to endogenous urinary loss	.198	1
Other unspecified N losses (as metabolic fecal N)	by difference from feeding trial maintenance data	.27	1.4
Probable D.C.P. required per day	average of feeding trial standards	0.65	3.4

These relationships can be expressed in an equation as follows:

$$\text{lb D.C.P./day} = \frac{146(W_{kg}^{.75}) \times 6.25}{454 \times 1000} \times (1 + 1 + 1.4)$$

This equation is a general one, applicable to all species to which the corresponding energy requirement equation applies.

As is the case with energy, it is often desirable in practice to express protein need in terms of the total instead of the digestible value. One practical reason for this practice is the fact that all commercially prepared rations or mixed protein supplements must be guaranteed as to minimum total crude protein. If animal requirements are shown only in terms of digestible crude protein, we must make a conversion if the standard is to be useful as a direct guide to the preparation of rations.

Some may argue that conversion is not feasible, because the digestibility of protein of different feeds is variable and no satisfactory working figure for converting digestible to equivalent total protein is, therefore, possible. This view may be questioned on the basis of published data, with the possible exception of roughages. Table 7.4 gives the coefficients of apparent digestibility of protein for the more commonly used concentrate feeds, from which we can see that individual feeds do not deviate widely from the average of 79%.

The standard deviation of individual feeds from this mean is ±4.7 units of percentage, and if we can assume that an average meal mixture carries not less than four feeds, then it follows that the standard deviation of the average digestible protein calculated for the mixure will be ±2.4 units and only once in twenty cases would we find that this average coefficient of digestibility of protein would differ by more than $\left(\frac{\pm 4.7}{\sqrt{4}} \times \sqrt{2} \times 2\right) = \pm 4.8$ percentage units from our original average of 79%. This variability is no greater than we may expect between the digestibility coefficients of different samples of the same feed. Obviously, therefore, for working values in the practical use of feeds we can often give valid figures for the total crude protein that correspond to the digestible crude protein. On this basis we may, then, also state the probable requirements of animals in

TABLE 7-4 *Coefficients of Apparent Digestibility of Protein of Concentrate Feeds* **(Morrison)**

Feed	% digestibility of protein
Barley	79
Barley feed (low grade)	74
Brewers grains	81
Buckwheat	75
Corn	76
Corn gluten feed	86
Cottonseed meal	81
Distillers grains	73
Emmer	80
Fishmeal	81
Hominy feed	71
Linseed oilmeal	84
Malt sprouts	77
Milo	78
Oats	78
Rice (rough)	76
Rye	84
Soybean oilmeal	85
Wheat	86
Wheat bran	83
Shorts	85
Wheat screenings	70
Average and standard deviation	79 ± 4.7

terms of total protein by assuming that the digestible value is equivalent to *about* 80% of the total crude protein.

The digestibility of the protein of roughage feeds is lower than that for the concentrate feeds and is about twice as variable as measured by the standard deviation of eighteen common roughages. The figures are shown in Table 7.5.

Not only is the variability of the protein digestibility of forages rather variable, but in practical feeding it is seldom that any mix-

TABLE 7-5 *Coefficients of Apparent Digestibility of Protein of Some Roughage Feeds* (*Morrison*)

Feed	% digestibility of protein
Alfalfa	73
Bermuda grass	51
Blue grass hay	57
Brame grass	51
Buffala grass	54
Alsike	6B
Red clover	62
Cawper hay	68
Mixed grasses	50
Kafir fodder	52
Millet	60
Native western hay	60
Oat hoy	54
Orchard grass	60
Sarghum	56
Saybean	75
Sudan grass	56
Timothy	46
Average and standard deviation	63 ± 8 5

ture of roughages will be fed at any given time. Consequently, it is less feasible to attempt to express protein requirements in terms of total protein where the ration is to be made up essentially of roughage.

Protein Requirements for Growth

The general characteristics of the growth of young animals have been discussed in a previous chapter dealing with the energy requirements of growth. We must realize, however, that the energy requirements for growing animals do not represent a requirement for the deposition of tissue. Tissue growth, in young animals, is largely

protein in nature—if for the moment we can neglect the water and the skeleton growth Hence, obviously an important consideration in the rations of growing animals is the protein

The amounts of protein that should be found in the rations for growing animals will be affected by the size of the animal and by the rate at which new protein tissue is being formed And if we look at feeding standards individually, there does not seem to be any rhyme or reason to the figures shown as requirements Most of the figures for protein requirements for growing animals, however, have been determined in actual feeding trials and, consequently, are not to be taken as mere estimates On the other hand, if the information that is available concerning protein requirements is to be useful in the practical feeding of animals, we must find some common basis of expressing these requirements in terms of the per cent of protein in rations

We have already shown in a previous discussion in this book, that the energy requirements and the protein requirements bear a definite relation to each other for adult animals, and it seems reasonable to believe that the same thing might be true in the case of growing animals at any particular stage of growth

Gilbert and Loosli* have attempted to bring some order out of the masses of data in the various feeding standards, and in 1951 published their report under the heading "Comparative Nutrition of Farm Animals" These authors found that at physiologically equivalent ages the nutrient requirements for protein, calcium and phosphorus are similar for the various species if expressed as a concentration of the TDN requirement The ratio of these nutrients to the energy intake changes with advancing age because of the change in the composition of the growth increments If they expressed the digestible protein as a percentage of the TDN requirement, these authors found it possible to prepare a generalized recommendation for protein applicable to most species of farm animals The figures they present are found in the first four lines of Table 7-6 These form the basis, in part, of the data of subsequent lines

The important part of Table 7-6 at the moment is the data in the

* *J Animal Sci* V 10 p 22 (1951)

TABLE 7-6 *Calculation of per Cent of Protein Needed in Meal Mixtures for Growing Swine or for Dairy Cattle*

		% adult weight atto ned (Swine)					
		10	20	30	40	50	60
Average weight[1]	lbs	50	100	150	200	250	300
Total daily feed[1]	lbs	3	5 3	6 8	7 5	8 3	8 8
Da ly TDN[1]	lbs	2 3	4 0	5 1	5 6	6.2	6 6
D C P as % of TDN[1]		18	16	14	13 5	12 1	11 4
Pounds feed							
grain[2]		3	5 3	6 8	7 5	8 3	8 8
roughage[3]		0	0	0	0	0	0
Pounds protein[4]		52	8	89	94	94	94
% total protein needed in meal mixture[5]		17	15	13	12 5	11 3	10 7

		% adult weight attained (Dairy Cattle)					
		10	20	30	40	50	60
Average weight[1]	lbs	140	280	420	560	700	840
Total da ly feed[1]	lbs	3 5	8 0	11 4	14 0	17 0	19 5
Da ly TDN[1]	lbs	2 8	5 0	6 6	8 0	9 2	10 1
D C P as % of TDN[1]		20.7	14 8	12 3	10 6	9 6	9 0
Pounds feed							
gra n[2]		3 5	4 0	4 0	4 0	2	1 5
roughage[3]		0	4 0	7 4	10 0	15	17
Pounds prote n[4]		.73	92	1 02	1 06	1 11	1 13
% total protein needed in meal mixture[5]		21	15	14	12	11	9

[1] From Gu lbert and Loosl , *J An Sci* V 10 (1951) p 22 31

[2] Grain = 75% TDN with protein 80% d gestible

[3] Roughage = 50% TDN and 6% D C.P

[4] Pounds protein = $\frac{\text{TDN} \times (\%\ \text{protein in TDN})}{80\%}$ i e $\frac{2\,3 \times 18}{80} = 52$

[5] % prote n = $\frac{\text{lbs prote n} - (\text{lbs roughage} \times 6\%)}{\text{lbs meal}}$ i e $\frac{52 - 0}{3} = 17\%$

* And appl cable to growing beef cattle not being fattened

last line, which indicate the approximate percentages of total crude protein that should be found in the meal mixtures intended for the two classes of stock noted according to the stage of development of the animals

Protein Requirements for Lactation

We can give a statement for the protein requirements for lactation somewhat more easily than we could for growing animals, because the problems involved are less complicated Lactation represents a direct loss of protein to the body, which, obviously, must be replaced, and we can calculate the extent of this loss in a relatively straightforward way Experimental evidence indicates that animals are able to adjust themselves with respect to lactation over a relatively wide range of protein intake, which seems to range all the way from one to six times the quantity of protein that has been excreted in milk Many dairy cattle research workers feel that if we add to the maintenance requirement enough protein to replace that lost to the hody in the milk produced plus about 25%, we meet the minimum requirements for lactation No distinction is made between milks of differing fat content insofar as protein requirement is concerned Nor is there any evidence that feeding more liberal protein than is called for by 1 25 times that of the milk is harmful The only reasons for feeding minimum allowances appears to be one of economy

SUGGESTED READING

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Swine (1953)
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CHAPTER 8

Requirements for Minerals, Vitamins, and Miscellaneous Additives

Minerals

FEEDING STANDARDS have only recently included data on the needs of animals for mineral elements, and then it has been largely limited to calcium and phosphorus Nevertheless information has been accumulating regarding all of the dozen elements which we now consider as essential These are conveniently grouped into macro and micro elements, the former being the ones ordinarily discussed in terms of pounds or kilograms, and the latter those described in terms of grams, milligrams, parts per million, or other terms applicable to very small units or quantities

All of the N R C Standards give figures for the quantities of calcium and phosphorus believed needed by animals, and sometimes also the standards show the common salt requirements The quantities, however, are much less certainly established than they are for energy and protein In general they are on the liberal side, especially in the case of phosphorus Nutritionally these liberal values may not be particularly serious, because animals appear to be tolerant of a considerable excess of both calcium and phosphorus, and probably of several other elements as well We have only to examine the figures for the calcium and phosphorus content of feeds used in livestock feeding to realize that many rations which have been successfully

fed contain these two elements in amounts and proportions that differ widely from the presumed requirements For feeds commonly fed to cattle and sheep this variation is graphically shown in charts prepared by Dr G Bohstedt* of the University of Wisconsin (see Figs 8-1, 2, and 3)

The wide tolerance, where adequate drinking water is available, of all farm stock for salt is well known to feeders generally

The problem of excesses of Ca, P, and NaCl is not the same for each Salt is commonly supplied as an ingredient of a mixed mineral supplement Here it acts not only as a nutrient but as a condiment to encourage free choice consumption of the mineral mix which otherwise might not be readily eaten Obviously as the proportion of salt in the mix increases, the quantities of the other ingredients must decrease This excess of salt could easily defeat the purpose of the mineral supplement, especially in the case of calcium and/or phosphorus, which are needed in amounts approaching those of salt Economically there may be a temptation for the manufacturer of salt-containing mineral mixtures to include such a large percentage of salt that the mix is no adequate protection against calcium and phosphorus shortage

The latest revision of the Canadian *Feeding Stuffs Act* includes a regulation dealing with this situation It merely specifies that if salt is an ingredient of a mixed mineral supplement that also supplies calcium and phosphorus, it cannot exceed 25% in a swine, or 33% in a cattle or sheep supplement (see Appendix II, page 420)

The excessive use of phosphorus becomes a problem where the carrier contains fluorine, as many of them do, especially those in the lower price groups We discuss fluorine problems elsewhere in this book (Chapter 13)

The problem of excessive use of calcium sources in a mineral mixture is usually one having to do with the effects on the quantities of phosphorus (and perhaps also of salt) that can be present, and arises mostly because ground limestone is cheaper than phosphorus carriers In general no supplementary calcium (without phosphorus)

* *Proceedings* Semi Annual Meeting of the Nutrition Council of the American Feed Manufacturers Ass (1951)

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* *Proceedings*, Semi-Annual Meeting of the Nutrition Council of the American Feed Manufacturers Ass (1951).

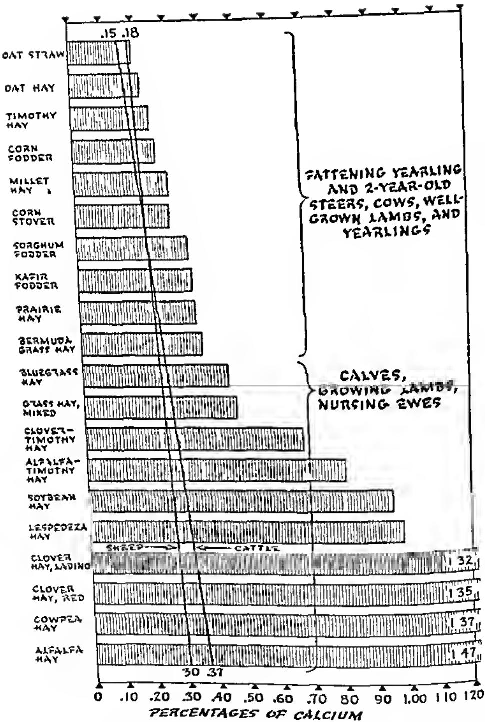

Fig. 8-1. *Calcium contents of common forages, and recommended percentages of calcium in rations for cattle and sheep (The diagonals represent the minimum to maximum feeding standard requirements for the classes of animals bracketed)*

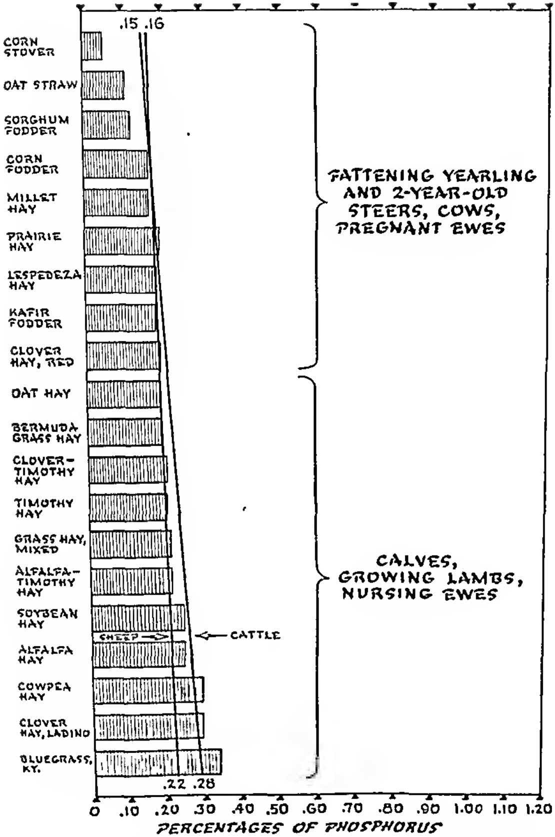

Fig. 8-2. *Phosphorus contents of common forages, and recommended percentages of phosphorus in rations for cattle and sheep. (The diagonals represent the minimum to maximum feeding standard requirements for the classes of animals bracketed.)*

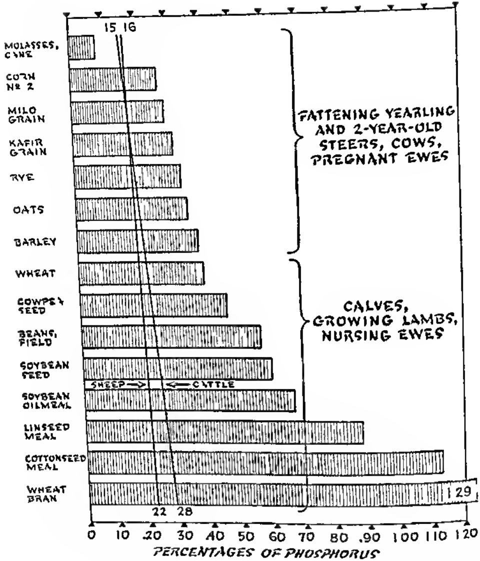

Fig 8-3. *Phosphorus contents of common concentrates (The diagonals represent the minimum to maximum feeding standard requirements for the classes of animals bracketed)*

is needed with herbivorous rations, but with swine and poultry rations that do not include roughage there may be more demand for calcium than for phosphorus This species difference is also recognized in the regulation in the Canadian *Feeding Stuffs Act* covering mineral mix tures, by restrictions on the maximum and/or minimum ratios between

calcium and phosphorus permitted in mineral supplements (see Appendix No 2, page 420)

The Trace Minerals. The quantitative data here are limited, and those responsible for the N R C Standards have not been prepared to specify "requirements" But as a guide to the use of the trace minerals in rations, we have assembled in tabular form the tentative figures given by various research workers for the several elements (see Table 8-1)

TABLE 8-1 *Summary of Some Recommendations Regarding Needs of Livestock for Trace Minerals*

	Beef Cattle and Sheep	Dairy Cattle	Hogs
Iodine	Salt at 01% KI	Salt at 007% I_2	Salt at 01% KI
	Salt at 0076% I_2		0 2 mg /100 lbs live weight daily to pregnant sows
Cobalt	0 1 ppm of dry feed	1 0 mg /day/1000 lb cow	0 9 mg /lb dry feed
	0 1 mg /100 lbs live wt daily	0 1 ppm of dry feed	
	0 03 mg /lb dry feed		
Copper	50 mg /1000 lb cow	10 mg /1000 lb cow	5 ppm of dry feed
	5 mg /sheep	0 03% of mineral mix	2 mg /pig
		(1 gm /100 lbs live-weight is maximum tolerance)	5% of supplementary iron to baby pigs
		1% copper sulfate in free choice feed mineral mix	
Iron	002% Fe in dry feed	50 ppm in dry feed	
	28 mg /kg liveweight	0 1% FeO_4 in mineral mix	
Magnesium		4 mg /1000 lb cow	
		06% in dry feed	
Manganese	7 mg /lb dry feed	7 mg /lb dry feed	12 ppm. of dry feed
		30 ppm. in dry feed	

Vitamins

Another expansion of feeding standards has been the consideration of vitamin needs Here we find a sharp species difference, as we need give no attention to the B-complex with herbivora With cattle, sheep and horses, however, Vitamin A and sometimes D are now thought often to be needed in excess of that supplied by their forage and grain The quantitative figures are given in the N R C Standards and need no further comment here (see Chapter 9) The needs of these species for Vitamin D is recognized but no figures other than for young animals have been suggested

For swine the requirement figures cover, in addition to Vitamins A and D, five B fractions for all classes, as well as choline and B_{12} for the very young animals Of the required vitamins the feed will probably have to make provision for sources of carotene, riboflavin, and pantothenic acid in rations for different classes of this species

Antibiotics

While this book does not discuss in any detail the physiological roles of the nutrients needed by livestock it may be in order to depart from this position somewhat in order to give consideration to the problem of whether or not to fortify rations with antibiotics Since any judgment and decision we may make in the matter depends in part on what function these products have, and since there is not in the usual scientific or in the animal husbandry literature any broad summary of the present knowledge we shall attempt here to present a condensed statement of what now appears to be known with respect to these substances Probably the most comprehensive review of the nutritional effects of antibiotics is given in the *Fine Chemicals Technical Bulletin No 3* (1955) of the American Cyanamid Company under the authorship of T H Dukes and W L Williams of the Lederle Laboratories Division We have taken from this publication most of the material summarized here

The most concise statement that has appeared as the reason for

feeding antibiotics is given by Dukes and Williams in these words "It is logical to expect that the rate of growth of an animal will be increased when a pathogenic or debilitating infection has been eliminated" That this is, in fact, the function of antibiotics fed as feed adjuvants is now reasonably well established The lines of evidence that support the view that their growth effect is due to antibacterial action in the intestinal tract has been summarized by these authors as follows

1) The antibiotic growth effect is shared by a group of substances of diverse chemical characteristics The only known property which these substances have in common is their antibacterial potency
2) Aureomycin, penicillin, and streptomycin were ineffective in promoting the growth of chick embryos when injected under sterile conditions "Germ free" chicks did not show a growth response to antibiotics and neither did chicks which were kept under conditions which tended to reduce or eliminate contact with bacteria, thus indicating that the growth response is dependent upon an antibacterial effect
3) Injected aureomycin and penicillin showed at the best a weak growth-promoting action as compared with their effect in the diet Any growth promoting effects produced by injection could be explained by the excretion of a part of the injected dose into the intestine
4) Bacitracin and streptomycin, which are not readily taken up from the gut, have a growth promoting effect when added to the diet of chicks, thus implying that the effect is due to their activity in the intestine
5) Despite its wide antibacterial potency, chloramphenicol has only a weak antibiotic growth effect, which may be due to the fact that this antibiotic is absorbed through the gastric wall and hence does not tend to reach the intestinal tract when added in small quantities to the diet
6) Hydrolysis with penicillinase led to a disappearance of the growth-promoting activity of penicillin in chicks The antibacterial potency was also destroyed by this treatment

We do not know how antibiotics affect the intestinal flora There is evidence to support at least three possibilities viz (1) They may inhibit or destroy organisms that produce subclinical infections, (2) they may increase the number or activity of organisms that synthesize growth factors which are ultimately available to the host,

and/or (3) they may inhibit organisms that compete with the host for nutrients

Of these the first is already well supported by experimental evidence from studies with poultry and pigs There is evidence also that inclusion in the ration of one or other of the now common antibiotics can be expected under most practical conditions to result in an increase in feed intake and often, though not always, an increase in feed efficiency in producing gains The more often noted effect of the increased feed intake is a corresponding increase in weight gain Growth of pigs is commonly stimulated by 10 to 15%, with feed efficiency improved in the order of 5 to 7% Such difficulties as diarrhea are usually easily controlled and unthrifty pigs often show marked improvement in performance

Another consequence of antibiotic inclusions has been a decline in the need for protein level of the pig ration This effect must be an indirect one, and it may be related to the nutrient needs of the different types of microorganisms of the intestinal tract of the pigs

In this connection, however, we should again point out that protein has been erroneously credited and/or blamed for many effects in livestock feeding The levels of protein recommended and used by some feeders and, indeed, by some investigators have been appreciably higher than those others have found adequate The reduction made possible by antibiotic feeding has been more apparent where the higher protein recommendations were being followed previously

The increased feed consumption and consequent increased gains have led to some misgivings insofar as pigs in the "finishing" stages are concerned Increased feed intake at this stage normally results in fatter carcasses—a condition incompatible with high quality bacon There are reports from several experiments suggesting that this effect is negligible, or even that no such effect exists We should point out, however, that all biological reasoning leads to the conclusion that extra energy intake above maintenance needs must result in fattening in proportion to the ratio of energy intake and energy of the tissue formed And experimental evidence from stations in areas where the more critical specifications of fat and lean in an acceptable

bacon rasher are used, has led investigators in such areas to recommend the removal of antibiotics from the rations of bacon hogs after they have reached the "finishing stage" (i e , weights of about 125 pounds)

Experiments show that the beneficial effect of antibiotics in poultry and pig feeding are also likely in calf and lamb feeding Calf scours in particular are usually well controlled by antibiotics

It is not appropriate here to discuss in further detail the nature or extent of the response given by animals to antibiotic feeding We have said enough to indicate the desirability of including one or other of these substances in the rations of young animals kept under usual farm conditions The beneficial effects are likely to be inversely proportional to the degree of sanitation of the housing quarters Antibiotics show no effects in environments in which bacteria are absent Better than average sanitation therefore tends to nullify in part the growth effect of antibiotics This conclusion should not be interpreted to mean that sanitation can justifiably be neglected merely by the use of antibiotics There are obviously other reasons for sanitation

The problem we must consider now has to do with the quantities to be used Evidence is not complete nor is there agreement between recommendations Insofar as swine feeding is concerned the committee that is responsible for the N R C Swine Standards has stated its position in the matter as follows.

> A summary of all the antibiotic work conducted with swine to date shows the following effects *Growing pigs* (1) It increases growth rate an average of 10-20 per cent The higher over-all nutritive value of the ration, the less the improvement of growth due to antibiotic additions (2) It may increase efficiency of feed utilization up to 5 per cent With certain poor quality rations, the efficiency of feed utilization may be increased considerably more (3) Antibiotic feeding tends to reduce the amount of protein supplement needed in the ration for swine It is not yet clear how much of the protein-sparing effect is due to the antibiotic and how much to a ration more adequate in B_{12}, riboflavin, niacin, pantothenic acid, and other nutrients Evidently, protein requirements have been high in the past because protein supplements were supplying factors other than amino acids (4) The greatest beneficial effect from antibiotics is observed during the early growth period Older animals are benefited by antibiotic supplementation, but the improvement in gain

is not as great as for younger animals (5) When antibiotics are fed to a weight of 100 125 pounds and then dropped from the diet, the pigs slow down in rate of gain Thus for continued maximum growth it is necessary to feed antibiotics from weaning to market weight (6) When antibiotics are fed to fattening pigs (i e, market pigs over 100 pound weight) a fatter carcass is likely to be produced (7) Runty pigs and/or young pigs suffering from scours respond markedly to antibiotic feeding (8) Antibiotic feeding results in a more uniform group of pigs by market time (9) Antibiotics increase bloom and in some cases are effective in preventing a skin dermatitis (unidentified type) with certain rations (10) Antibiotics give a favorable response with pigs both in drylot and on pasture (11) At present there are insufficient data to conclude that combinations of antibiotics are more effective than any single one used at the appropriate level (12) A level of 5 milligrams of antibiotic per pound of total ration (10 gm per ton) or 25 milligrams per pound of a protein supplement (50 gm per ton) which is intended to be fed free choice with grain is probably quite near the desirable level of antibiotic feeding This level may vary somewhat, depending on the antibiotic, the ration used, and environmental conditions

Breeding stock and suckling pigs (1) There is some evidence to indicate that the feeding of antibiotics to pregnant sows at levels of 10 to 15 milligrams per pound of ration may increase the birth weight and livability of pigs (2) Antibiotics are not transferred through the milk of sows in sufficient amounts to show a marked stimulation in the growth of nursing pigs (3) Feeding antibiotics to pigs in creep rations during the suckling period will increase the weaning weight 5 to 10 pounds at 56 days of age *

SUGGESTED READING

Guilbert H R and Loosli, J K "Comparative Nutrition of Farm Animals *J Animal Sci* V 10 No 1, p 22 (1951)

Jukes, T H, and Williams, W L, Nutritional Effects of Antibiotics" *Pharm Revs* V 5 No 4 (1953)

Proceedings Nutrition Council *Synposium on Mineral Requirements of Animals* Am Feed Manufacturers' Assn, Chicago, Ill

* N R C *Nutrient Requirement of Swine* (1953)

CHAPTER 9

Feeding Standards

ACCORDING to orthodox definition a *feeding standard* is a table in which is recorded what is believed to be the daily need of a specifically defined animal for one or more of the recognized nutrients. Standards have been proposed for most of the kinds of animals that are kept in captivity, and some of them date back at least to 1810.

In 1943 the Committee on Animal Nutrition of the U.S. National Research Council embarked on a long time project of preparing and keeping up-to-date by periodic revision a set of modern feeding standards for the several species of animals which are kept in captivity, including not only the so-called farm animals and poultry, but fur-bearing animals, dogs and some laboratory animals. To deal with each species, a small committee of specialists is appointed to review the literature and from it to prepare a table of nutrient needs. The sub-committee proposals are then reviewed by the parent N.R.C. Committee on Animal Nutrition. By this means the uniformity of style as well as of general policy is more easily arranged. When finally approved, the standards, called *Nutrient Requirements for Swine* (or *Poultry*, or *Beef Cattle*, etc.) are published in pamphlet form. The nominal sale price (50¢) is used to maintain a revolving fund to finance revisions, etc. The project makes available up-to-date tables on the nutrient needs of animals. The text also includes pertinent information not suitable for tabulation, as well as extensive

references to research literature aimed at establishing the requirements for specific nutrients

Since these standards are under constant review and revision, to attempt to duplicate them would be largely waste effort The basic tables from these N R C Standards of the nutrient requirements of the several feeding categories of swine, dairy, and beef cattle are reproduced elsewhere in this chapter Before referring further to them, however, we should consider feeding standards in general in order that they may be more correctly used in the preparation of animal rations

The Evolution of Feeding Standards

Tables of requirements have, over the years, become more specific and more inclusive as our knowledge of nutrient needs and of factors that determine and modify them has expanded Whereas early standards dealt chiefly with energy and protein for average animals, modern tables not only include caloric needs, but those for amino acids, vitamins and minerals as well and, in addition, they may be highly specific in defining the animal to which the requirement figures apply The evolution of the feeding standard, however, has been more a matter of additions than of quantitative revision It is worth noting that in the important standards for dairy cows that have been proposed since about 1900, there have been no important changes in the energy or the protein figures, either for maintenance or for milk production Significantly also the quantities of these two nutrients are essentially the same in all recent standards

The Nature of Early Standards. The philosophy underlying the objects of feeding standards is of interest and also of importance in using the figures Many of the standards in use (in fact most of the earlier ones) reflect the research, observations, and ideas of one man We might take as an example the tables that were presented by Kellner In his description of how he arrived at the maintenance energy and protein figures, he also states a typical philosophy regarding standards

He did his work on the maintenace of cattle with oxen at rest

He chose such animals because "the feeding of working oxen at rest is the simplest task which the owner of cattle has to undertake, they are practically sexless, little subject to nervous influence and except for slight growth of hair, hoof and horn, do not increase in size, nor do they perform any utilizable work " His aim was to feed them "so that the body does not need to supply any of its substance for the production of energy and that on the other hand, there shall be no excess of food to be made into fat " *

Kellner then proceeded to feed two groups of resting oxen, using an "insufficient" ration for one and a "sufficient" ration for the other He publishes the results of this typical experiment with figures assembled in Table 9-1

TABLE 9-1 *Example of Kellner's Energy Balance Studies to Establish Maintenance Needs of Cattle*

Animals	Digestible nutrients consumed				Gain or loss of	
	Protein	Fat	CH₂O	Starch equivalent	Flesh	Body fat
	kg	kg	kgs	kgs	gms	gms
III	35	10	6 17	4 00	−51	+139
IV	34	10	6 08	3 96	−57	+45
B	28	12	6 63	4 52	−144	−172
C¹	42	.21	6 58	4 60	−6	+1
Average	35	13	6 37	4 28	−65	+3
V	60	07	6 45	5 04	+48	+235
VI	57	07	6 31	4 64	+26	+263
20	65	.20	6.78	5.76	−7	+158
A	56	18	6 62	5 44	+66	+227
C²	54	28	7 26	5 04	+161	+37
Average	59	20	6 68	5 20	+59	+184

The exact rations used are not particularly important if we assume for the moment that the digestible protein, fat, and carbohydrate

* Kellner *The Scientific Feeding of Animals* Chap II, The Macmillan Co , N Y (1913)

have the same usefulness regardless of their origin Kellner points out that such an assumption is not always justified—a fact we appreciate fully today He corrects in part for this assumption by expressing the total energy intake in terms of starch equivalents (see Chapter 3)

The conclusions Kellner arrives at from these data are of interest He states " it suffices for maintenance to give 0 5 kg digestible protein and 5 2 kgs starch equivalent As, however, in practice it is not advisable, owing to the individuality of the animals, to restrict the feeding to the absolute minimum, it is preferable to reckon per day 0 6 0 8 kg digestible protein and 6 0 kgs starch equivalent This standard assumes that coarse fodder will be used and any deficit in protein will be made good by oilcakes, etc Such rations contain sufficient mineral substances, for investigations have shown that daily consumption of 50 gms phosphoric acid and 100 gms lime per 1000 kgs body weight will meet all requirements "

These data and comments by Kellner illustrate several characteristics inherent in most Feeding Standards For example, we can see from the data of Table 9-1 that the variability between animals in nutrient intake and in their response in body weight is considerable In this connection we should note that from a study of a large number of feeding trials (Crampton, 1933) it was concluded that for normal feeding trials the variability that could be expected between animals within lots as measured by the standard deviation was relatively constant for different trials The average coefficients as a percentage of the means are shown in Table 9-2

TABLE 9-2 *Probable Average per Cent Variability Between Animals Within Lots of Gain Feed Consumption, and Gains per 100 lbs Feed Eaten*

Measurement	Hogs and cattle (S D in %)	Sheep (S D in %)
Live weight gains	17	21
Feed consumption (90% dry matter)	13	16
Feed required per 100 lbs. gain	11	13

If we apply the appropriate coefficient to the means of Table 9-1 (assuming that variation in feed required per 100 lb. gain is a direct reflection of variation in nutrient need), the probable necessary intake per 1000 lb. weight, in protein and in starch equivalent to meet the maintenance needs of 95% of cattle under practical feeding might be taken as 0.72 and 6.34 lbs. respectively (see Table 9-3).

TABLE 9-3 *Probable Maximum Protein and Starch Equivalent Requirement of Kellner's Oxen*

Measurement	Mean ± S.D. × 2	Maximum probable need	Kellner's maximum
Protein (lbs.)	0.59 ± 0.13*	0.72	0.8
Starch equivalent (lbs.)	5.20 ± 1.14†	6.34	6.0

* .59 × 11% × 2 = .1298
† 5.2 × 11% × 2 = 1.144

In his standard, Kellner has increased his observed average protein to a maximum of 0.8 lb. and the starch equivalent to 6.0 lbs. per 1000 lb. body weight. In the former his margin is rougly 35% over his observed average, or 10% over the probable maximum need to adequately nourish a 1000 lb. ox. For energy, however, he raises his standard only 15% above his mean which is at least 5% below what one such animal in 20 might be expected to need for its maintenance.

These figures are cited to call attention to three points. First, the figure in a feeding standard, given as the requirement for a nutrient. is usually considerably above the actual average intake of the group of animals whose performance was judged satisfactory. It is set at a level the *investigator believes is safe*—one he believes guarantees that all comparable animals will be adequately provided for.

Second, the magnitude of the margins over the actually observed satisfactory intakes applied to different nutrients are not consistent. Such margins seldom bear any conscious relation to normal variability of the animals described, or to the variability of the nutrient in different samples of the kinds of feeds used in the feeding tests.

There is no particular objection to the feeding of rations that are more liberal than actually needed There is objection, however, to including such excesses as a part of *requirement figures* Such figures become a mixture of true requirement plus some extra allowance, the magnitude of which represents an opinion without experimental basis When a feeder has to adjust feeding to produce some particular result, such standards are of uncertain value

The third matter is that of *other nutrients,* consideration of which was not a part of the primary objective of the particular comparative feeding test Kellner says, in effect, that neither phosphorus nor calcium need be considered, because the feeds used already supplied more than the quantities *other studies* had shown to be enough This statement raises an important question in connection with some modern standards, namely, whether the results of different and unrelated studies can be assembled into a montage of nutrients to give a recipe for a nutritionally complete diet

The Significance of Balance Between Nutrients and Energy

The answer is not straightforward nor simple, but the basic factors involved are (1) whether the nutrients in question are interrelated or interdependent in function, and (2) whether seemingly comparable animals will react the same to identical rations We should consider both questions

With respect to energy and protein, Brody's classical studies in this field* have brought together data, from which it is evident that irrespective of species there is a close relationship between the fasting protein (nitrogen) and fasting energy catabolism in the adult (see Chapter 7) When we make our calculations on the basis of adult maintenance, we find that about 10% of the total calories should be derived from protein Research by Forbes† *et al* clearly demonstrates that increasing the protein level between equicaloric rations for maintenance causes a *decrease* in efficiency of the ration

* *Bioenergetics and Growth* (1945)
† *J Nut* V 28 p 189 (1944)

by increasing the specific dynamic heat production and decreasing the metabolizable energy. On the other hand, greater concentration of protein is required for the most efficient rations where growth or production are involved. The requirement is related to rate of growth or level of production as is also the increased energy demand. Consequently, the protein demand is related to energy need, though the proportions differ according to tbe extent and nature of the production or growth. Thus, it is clear that there is an optimum protein–energy ratio specific for particular conditions. Distorting this ratio by an excess of protein, contrary to being beneficial, actually reduces the efficiency of the diet.

Closely related to the energy requirement is that of several of the Vitamin B-complex, whose functions are primarily as components of enzyme systems involved in energy metabolism. Thiamine, for example, appears to be required at a level of about 0.23 milligrams per 1000 metabolizable calories. This figure is arrived at from analysis of many feeding trials, each conducted without reference to the others. Niacin is also required in proportion to calories, but the situation is complicated by the fact that tryptophane is a possible precursor of niacin. Therefore, before we can make a satisfactory statement of niacin requirement, we must know the amino acid intake. Since the tryptophane complication was unknown when early niacin studies were undertaken, obviously values for niacin needs may change in feeding standard revisions. Riboflavin requirement, on the other hand, appears not to be directly related to caloric requirement or to muscular activity, but rather follows protein intake. Insofar as calcium need is concerned, it is largely determined by skeletal size in the adult and by rate of skeletal growth, or the production of calcium-containing products. In practical feeding, phosphorus is usually supplied in some ratio to calcium.

That the nutrients are interrelated in function is thus clearly evident. Whether or not imbalance, especially in the direction of excesses of individual nutrients, is seriously harmful to the overall usefulness of the ration, is not so clear. In some cases it is obvious that relative excess is undesirable. For example, if the caloric value is greatly in excess of those nutrients that regulate and facilitate

energy metabolism, the ration efficiency will suffer and we may expect malnutrition The problem less often considered is should excesses be avoided in vitamins and minerals so that individually and/or collectively they are in proper relation to calories or protein?

Feeding Standards Describe Hypothetical Rations

A modern feeding standard based on the results of many feeding trials is a statement of what is believed to be the requirement of some selection of nutrients, each treated as though it were an independently acting entity The novice might visualize the standard as a formula, with each nutrient a separate ingredient to be mixed into a batch for feeding However, most feeds contain a wide assortment of nutrients The proportions in which they occur are seldom identical even between feeds that practical experience as well as experimental tests have proven to be mutually exchangeable in the ration The obvious conclusion must be that while for maximum efficiency each nutrient may have an optimum concentration in the ration in relation to other nutrients, there is no way in which an "ideal" ration as described by a feeding standard can be prepared

We do not mean to say that the selection of feedstuffs for a 'balanced' ration should be made without reference to specific nutrient contents By appropriate choices, we can make a nutrient assortment more nearly like the "ideal" than we could by blind substitution Protein levels, for example, are normally adjusted quite closely to standard requirements, and by careful choice of feeds we can easily avoid gross shortages of amino acids

However, in substitution one must usually choose between a variety of evils Replacing corn with oats raises protein and increases tryptophane, but reduces available energy through increasing fiber And so we find that in practical ration formulation we make a rough balance of nutrients according to a feeding standard through selection of available feedstuffs within the limitations of relative costs, and then make further needed adjustments by the addition of pure nutrients or concentrates of such nutrients to eliminate any apparent remaining deficiencies

Biological Tests of Feeding Standards

The facts are that to a large extent feeding standards describe purely hypothetical rations None of the standards has ever been critically tested as a complete working unit Indeed, research men have shown an unexplainable lack of curiosity as to whether a ration compounded in accordance with a given standard will prove to be ideal from the standpoint of the animal fed Yet the authors of such standards proclaim them as guides to feeding, and feed manufacturers use them as a basis for the fortification of feed mixtures intended to be properly "balanced" for feeding

On the other hand, this omission is not altogether mere negligence on the part of those setting up feeding standards To adequately test a feeding standard for farm livestock is no mean undertaking The numbers of classes of dairy animals for which nutrient needs are described in the N R C Table of Nutrient Allowances total 18 different liveweight groups, 4 milk fat level subcategories, plus a supplementary section for late pregnancy which effectively adds at least 5 additional groups To test the swine standard would involve feeding trials with 6 weight classifications of market pigs and 4 for breeding stock categories If, for each group of animals, a critical test of the optimum levels of each of the nutrients recorded were to be made, the project from the standpoint of numbers of animals needed and the facilities for their use in controlled feeding trials becomes fantastic We do not mean, however, that feeding standards should be accepted blindly or that no testing should be done, though there may be some misconceptions as to the extent of the applicability of such tests

A Unique Feeding Test

In this connection there exists a unique situation in Canada today in the system of Swine Advanced Registry Test Feeding Stations When it was decided to set up a scheme of Advanced Registration for Canadian swine based on the breeding performance of purebred

sows and the feed lot and slaughter records of their progeny, Feeding Stations were established in each province of the Dominion (excepting New Brunswick and Newfoundland) Two male and 2 female pigs from each litter to be tested are sent to one of the Stations, to be fed from weaning time (approximately) to a market weight of 200 lbs Pigs to be tested are nominated when the litters are two weeks old and are shipped to arrive at the Feeding Stations when 60-70 days of age The rations fed at the different Stations are mixed to one formula, and for the data to be cited below, were mixed centrally and shipped to each Station by the milling company that prepared them The formulae are reviewed and established periodically by a Feed Committee of the National Swine Board, based on cooperative comparative feeding trials conducted under their supervision at several Canadian universities

In 1949 the question was raised as to whether or not self-feeding should be introduced in these Feeding Stations, and before making a decision the Feed Committee arranged for a Dominion-wide comparative test In this study five of the Advanced Registry Feeding Stations, one each in British Columbia, Alberta, Saskatchewan, Ontario and Nova Scotia fed groups of purebred Yorkshire pigs from their respective areas on a meal mixture prepared according to committee specifications by one milling company in Ontario and shipped to each of the cooperating Stations There was one mixture for pigs from 75 to 125 lbs weight After this weight half the pigs at each Station were fed to market on a normal finishing mixture, while the others received this finishing ration diluted with 25% bran as a possible means of restricting fattening The study involved two complete replicates at each Station and was one of a series to establish official rations for bacon carcass production

When the pigs reached market weight of 200 lbs they were slaughtered at local abattoirs, and their carcasses graded, cut, measured and scored by Government Graders in accordance with the requirements of the Official Swine Advanced Registry Carcass Scoring Scheme

This study involved only purebred Yorkshire pigs Nevertheless, it represented animals comparable as to age and sex but coming from

geographic areas as far separated as 3000 miles. Thus, types and strains within one breed such as develop within "local areas" were fed on identical rations under comparable management conditions.

An examination of the nutrient make-up of these rations, which were intended to be adequate, and of the performance of the pigs is enlightening in a general consideration of feeding standards.

In Tables 9-4, 5, 6, and 7 we give the ration formulae; their calculated contents of those nutrients listed in the U.S. Swine Standard; and the feed intake, gain, and feed efficiency data for (1) the growing ration, (2) the normal finisher, and (3) the bran-diluted finisher, respectively. Included for comparison in each are the figures for a hypothetical nutrient mixture suitable for market pigs as calculated from the U.S. Swine Standard as well as the expected performance of pigs fed on such an ideal ration. The discrepancies are calculated as the per cent by which the Canadian test rations or the performance of the pigs exceeded (+) or failed (−) to meet the standards.

TABLE 9-4 *Rations Used in Canadian Advanced Registry Carcass Test (1949-50)*

Ingredient	Grower	Normal finisher	Diluted finisher
	lbs.	lbs	lbs.
Barley	430	460	360
Wheat	170	180	140
Oats	250	280	220
Bran			200
Tankage	75	40	40
Fish meal	22.5	12	12
Linseed meal	37.5	20	20
Salt	7.5	4	4
Limestone	7.5	4	4
Total	1000	1000	1000

In Table 9-5 the nutrient content of 1000 lbs. of the mixture fed to the pigs from weights of about 75 lbs. to 125 lbs. is shown in comparison to that set out in the U.S. Standard for 100 lb. market pigs. The "poor fit" will no doubt surprise many.

TABLE 9-5 *Comparisons of Grower Ration with Feeding Standard*

Nutrients per 1000 lbs. of mixture		Grower ration (100 lb. pig)		
		As fed	U.S. Standard requirement	Difference (%)
Protein	lbs.	170	140	+21
TDN	lbs.	692	750	−8
Calcium	gms.	4261	2948	+45
Phosphorus	gms.	3080	2041	+51
Salt	gms.	3405	2268	+50
Thiamine	mgs.	2588	491	+427
Riboflavin	mgs.	1363	1000	+36
Niacin	mgs.	20476	5000	+309
Ca Pantothenate	mgs.	4073	4498	−9
B_{12} (added)	mcgs.	0	5	
Carotene	mgs.	140	756	−81
Vitamin D	I.U.	36000	90000	−60
Daily feed	lbs.	4.7	5.3	−11
Daily TDN	lbs.	3.4	4.0	−15
Daily gain	lbs.	1.3	1.6	−19
Feed per 100 gain	lbs.	383	332	+15
TDN per 100 gain	lbs.	274	250	+10

Results of Canadian Feeding Test. First, the protein level is some 20% higher than "needed." Here is a fundamental problem. The standard calls for 14% crude protein. The Canadian basal feed mixture for reasons of economy is based on barley, wheat, and oats and carries 12.9% crude protein. In order to include in the mixture enough proteins of animal and marine origin to insure the quality of protein believed needed, it was impossible to keep the protein of the final mixture down to 14%. Had the basal mixture consisted of corn, it would have been possible to include 15% of a 40% protein supplement and still not exceed 14% protein in the mixture, but with the basal feeds economically available in Canada, the use of 15 parts of mixed protein supplement in 100 resulted in 17% protein in the completed mixture.

TABLE 9-6 *Comparison of Hog Finisher with Feeding Standard*

Nutrients per 1000 lbs of mixture		Normal finisher (150 lb pig)		
		As fed	U S Standard requirements	Difference (%)
Protein	lbs	147	130	+13
TDN	lbs	698	750	−7
Calcium	gms	2403	2500	−4
Phosphorus	gms	2392	1510	+58
Salt	gms	1816	2280	−20
Thiamine	mgs	2668	500	+433
Riboflavin	mgs	1362	1000	+36
Niacin	mgs	20096	5000	+302
Ca Pantothenate	mgs	4017	4500	−11
B_{12} (added)	mcgs	0	—	
Carotene	mgs	2	442	−99
Vitamin D	I U	0	90000	
Daily feed	lbs	7 4	6 8	+9
Daily TDN	lbs	5 1	5 1	0
Daily gain	lbs	1 6	1 8	−11
Feed per 100 gain	lbs	455	378	+20
TDN per 100 gain	lbs	318	283	+12

The use of coarse grains, barley and oats, has diluted the TDN to some 69% as compared to about 75% considered normal for U S hog rations The consequences are two-fold Either the daily feed intake must increase above "normal" or the gains will be expected to fall below standard And, in either case, the feed required per pound of gain will increase, i e , the feed efficiency will decrease

The pigs in this test, however, did not eat more, but less feed per day that called for in the standard Thus, TDN intake was doubly depressed from that expected, and gains were 19% lower than "normal" There was no report of goose stepping among any of the pigs, and so one questions whether the 9% deficiency of pantothenic acid was detrimental Nor was there clinical evidence of Vitamin D shortage Concerning Vitamin A, there is room for argu-

TABLE 9-7 *Comparison of Modified Hog Finisher with Feeding Standard*

Nutrients per 1000 lbs. of mixture		Diluted finisher (150 lb. pig)		
		As fed	U.S. Standard requirements	Difference (%)
Protein	lbs.	155	130	+19
TDN	lbs.	670	750	−11
Calcium	gms.	2439	2500	−2
Phosphorus	gms.	3242	1510	+115
Salt	gms.	1816	2280	−20
Thiamine	mgs.	2819	500	+460
Riboflavin	mgs.	1322	1000	+32
Niacin	mgs.	38104	5000	+662
Ca Pantothenate	mgs.	5487	4500	+22
B_{12} (added)	mcgs.	0	—	
Carotene	mgs.	2	442	−99
Vitamin D	i.u.	0	90000	
Daily feed	lbs.	7.1	6.8	+5
Daily TDN	lbs.	4.8	5.1	−6
Daily gain	lbs.	1.5	1.8	−16
Feed per 100 gain	lbs.	485	378	+28
TDN per 100 gain	lbs.	324	283	+14

ment except for the fact that pigs of this age could hardly have become depleted to the point of growth restriction unless they had been nursing very Vitamin A deficient mothers, a situation that seems unlikely in view of the widely different sources of the pigs and the fact that they were from high class breeding herds. All of the other nutrients considered were consumed in excess of standard requirements.

It would seem, therefore, that the feeding standard was not only liberal in its requirement figures, but too high in the values for normal feed intake and for expected live weight gains for pigs of this category.

In Table 9-6 similar data are presented for the ration fed these

pigs from the time they weighed 125 lbs. until they reached 200 lbs. market weight. Here, the same general picture is evident with respect to ration nutrients. But these heavier pigs have voluntarily eaten 9% more feed per day than is indicated as "normal," and by so doing have consumed the same quantity of TDN as that called for in the standard. There can be no argument, therefore, that lower than standard concentrations of pantothenic acid and of carotene and of Vitamin D have checked feed intake with these pigs. Gains are 10% slower, however, and hence the TDN efficiency is below "expected" to about the same extent.

In Table 9-7 we see what happens when wheat bran is introduced. Protein is now almost 20% over standard, and TDN is reduced still further. Even with 5% above normal feed intake, TDN consumption is less than standard figures. This was the effect desired. The bran was employed specifically to reduce fattening rate by reducing TDN intake. Gains have actually been depressed 16% from standard and about 7% from that with the undiluted finisher.

Energy Intake Critical. In a critical consideration of these data we can see at once that the response of the pigs has been more closely related to level of energy intake than to any other ration factor. Neither the greater concentrations of protein, of calcium and phosphorus, nor of several of the vitamins have prevented the smaller daily gains than were given as expected in the standard.

In swine feeding we should keep in mind that market pigs are fed to produce a carcass, of which the consumer recognizes two kinds—fat ones and lean ones. The hogs on this Canadian trial were all subjected to official slaughter test. The detail of carcass measurements is of no importance but the overall result is; and of all the items considered and recorded, that of carcass grade is of the most direct significance. Carcasses that are classified as Grade A bring a cash bonus in addition to the regular grade price. Excessive fat deposition has consistently been the principal fault with Canadian hog carcasses that has kept them out of A Grade. The dilution of the energy value of the finishing ration with bran was done specifically to counteract the tendency for self-fed hogs to become too fat.

We may summarize the results briefly as follows The altered ration had no effect on any carcass measurements except those directly related to depth of fat The lower energy ration effected a 7% reduction in depth of back fat, which was reflected in an overall increases in carcass score of 4 percentage units and an increase of 27% in the proportion of Grade A carcasses The increase in grade was relatively uniform between Stations, and, again, indicates the particular sensitivity of animals to changes in energy intake

Variation in Response to Feed. Before finally drawing conclusions about feeding standards from the example just discussed, we should consider one further feature of these tests In this Canadian study it was possible to measure the variability of the response of pigs between replicates (which was, of course, really between groups of pigs within a local geographic area) and between Stations (which was between widely separated geographic areas) The first variations would be expected to be typical of differences between batches of pigs on the same farm or even between different farms of a restricted area keeping the same breed of pigs and following similar feeding practice The variability between pigs of different Stations will measure overall differences between different types or strains of pigs within one breed, differences due largely to hereditary background The results of such an analysis are shown in Table 9-8

In this table the maximum and minimum values above and below the means (i e , the fiducial limits) are twice the standard deviations for the variance for all causes and represent the limits of 95% of the population In other words, while only one lot in 20 would normally exceed these limits either way, one could expect individual lots that statistically belonged to this population to range in response anywhere between these values

We should note two things here First, in every case the figure given in the U S Standard lies within the fiducial limits of this study Secondly, insofar as voluntary feed intake and live weight gains are concerned, from 57 to as high as 88% of the differences between the separate feeding lots were traceable to Station, while within a geographic area the performance of the pigs was relatively consistent

TABLE 9-8 *Variability in Response of Pigs of Different Geographic Areas to Identical Rations*

Ration group	Criterion	Means from Canadian test pigs	Fiducial limits at $\pm 2 \times$ SD for total variability: Minimum	Maximum	Variability traceable to*: Replicate	Station	Expected mean value from U S Feeding Standards
		lbs	lbs	lbs	%	%	lbs
Growing pigs average 100 lb weight	Feed	4.7	3.1	6.3	5	85	5.3
	Gain	1.3	.8	1.7	10	88	1.6
	100 F/G	383	307	459	6	67	332
	100 TDN/G	274	216	332	30	57	250
Pigs finishing on normal ration Average 150 lb weight	Feed	7.4	5.5	9.3	5	73	6.8
	Gain	1.6	1.3	2.0	4	75	1.8
	100 F/G	455	397	513	1	58	378
	100 TDN/G	318	283	353	2	59	284
Pigs finishing on diluted ration Average 150 lb weight	Feed	7.1	6.1	8.2	9	60	6.8
	Gain	1.5	1.2	1.8	4	80	1.8
	100 F/G	485	413	557	1	44	378
	100 TDN/G	324	279	371	1	43	284

* Balance of variation due to interaction

Here we find much food for thought regarding the structure of feeding standards and their application as guides to ration formulation

Margins of Safety in Feeding Standards

The problem of the structure of feeding standards themselves is Can data for the requirement of separate nutrients taken from independent tests justifiably be averaged without precautions against a bias of the data from different types, strains, and breeds of animals, albeit otherwise comparable?

It is well known that different Experiment Stations develop facilities for different types of studies Thus, one group of workers will be intensively studying some Vitamin B problem, while another devotes its time to amino acid requirements The probability is that the inherent differences in animals between such Stations will be such that what are termed requirements for those at the one Station would not closely fit those of another Station It also follows statistically that if the values stated as requirements are not unbiased averages then margins defined by standard deviations above and below the means will not much improve the situation

This undesirable feature of feeding standards which are prepared by the assembling of scattered available data for the several nutrients individually is, to a large degree, unavoidable In this respect standards prepared as units from observations of animals of one herd may perhaps show more consistency with respect to the *relative needs* of the separate nutrients, especially in relation to the energy intake An attractive hypothesis is that more consistent standards would result if the pertinent nutrient data from appropriate tests were expressed in quantities relative to some measure of energy rather than in absolute values The fact that energy intake is so closely correlated with size and performance of animals often justifies its use as a base on which other nutrient needs may be expressed, even if no proven biological cause and effect relation is known

Description of Feeding Groups

A problem in the use of feeding standards, clearly shown in the results of the Canadian studies, has to do with the description of the animals or the feeding groups In many standards, at least by implication, we get the impression that not only is gain the important criterion of optimum nutritional intake but that maximum gain is the objective This conclusion is obviously not justifiable Some of this misconception could be eliminated by more complete description of the animals and the criteria of optimum conditions If gains are to be indicated they should perhaps show upper as well as lower acceptable

limits. Perhaps we need to include other criteria not now used to describe adequately the kind of animals for which the nutrient list is intended. Thus, a double standard of height-weight-age might be more fully descriptive of the size of growing cattle than weight alone. In pigs, breed or type sub-classification might help, in that long-bodied pigs show differences from shorter types of carcasses on slaughter, and should not necessarily be considered as of equivalent physiological age and development at equal live weights. Certainly there should be subgroups for market pigs beyond weights of 125 lbs. to describe separately hogs intended for fresh pork and those for bacon.

Concerning the discrepancies between the concentration of the several nutrients in the rations fed and that calculated from a feeding standard, we must draw conclusions cautiously. Certainly, there is no evidence of any detrimental effect of surpluses of any of the B-complex Vitamins recorded, or of their imbalance. In practical feeding, however, little can be done about excesses of a number of nutrients because of the wide differences between basal feeds in concentrations of these nutrients and the economic need of frequent substitutions of feeds in formulation of feeding mixtures.

The conclusions we can draw from these considerations of feeding standards may be rather generally stated as follows:

1) As distinct from tables of recommended allowances which usually are admittedly liberal in their quantities, feeding standards that claim to represent the actual needs of animals give values for the various nutrients that are sufficiently high so that there is seldom any justification for intentionally adding margins of safety to avoid nutritional deficiency.
2) The variation between animals in their response to identical assortments of nutrients makes it questionable whether standards should be used to measure adequacy of rations fed to individuals or even to small groups; rather, the data of feeding standards should be used as a guide to the relative nutrient make-up of meal mixtures for animals of specified feeding categories. Daily

allowances of such mixtures will be adjusted to the capacity of the individual animal or group or to the objective in question

3) Surpluses of non-toxic minerals and of vitamins are probably of little practical importance in a nutritional sense
4) Appropriate levels of (and perhaps balance between) proteins and energy components, must be maintained in feeding practice since these may influence promptly and markedly the animal's performance

Feeding Standards are Indispensable Guides

A word of caution may be in order at this point The discussions above are not to be taken as condemning feeding standards Advances in feeding practice over the past years have been greatly facilitated through the development of feeding standards and their wider use It should be obvious that they are still imperfect, however, and hence if used blindly may lead to faulty nutrition

Progress in scientific feeding of livestock parallels the refinement and expansion of feeding standards, and while it is doubtful that many practical livestock feeders ever use directly such standards, the extension of the knowledge of the nutrient needs of stock through schools, clubs, and meetings has resulted in the use of more efficient rations generally

We should not think of feeding standards as finalized statements of animal requirements Modern ones such as those issued by the various sub-committees of the N R C Committee on Animal Nutrition are under continuous review and revision Usually the revisions are downwards for specific nutrients This tendency is merely because where the requirement for a nutrient is first published by an investigator it is usually liberal As additional studies are completed to give more certainty to the figure, the average value gradually finds its proper level which is often appreciably below the first estimate

One must not, therefore, be surprised if the ration as made up in accordance with the currently used standard turns out to be at variance with a later revision of that standard Nutritionally any excesses which are involved are fortunately not likely to be serious

Modern Feeding Standards

In any case we cannot solve the problem by avoiding the use of feeding standards on the grounds that they are not finalized And, accordingly, we bave included in this book abbreviated tables show-

TABLE 9-9 *Daily Nutrient Requirements of Dairy Cattle, Based on Air-Dry (90% dry matter) Feed*

Weight of animal lbs	Total feed lbs	D C P lbs	TDN lbs	Ca gms	Phos gms	Carotene mgs	Vit D i u
			Growing Heifers				
100	2	40	2 0	7	6	4	300
200	6	60	4 0	13	10	8	600
400	11	80	6 5	13	12	16	
800	19	90	10 0	13	12	32	
1200	24	1 00	12 0	12	12	48	
			Maintenance Mature Cows				
800	14	50	6 8	6 4	8	32	
1000	16	60	8 0	8 0	10	40	
1200	18	70	9 2	9 6	12	48	
1400	21	80	10 5	11 2	14	56	
1600	23	87	11 4	12 8	16	64	
			For Reproduction—add to maintenance for last 3 months				
	8	60	6 0	8	7	30	
			Lactation—add to maintenance for each pound of milk				
3% fat		040	28	1	07		
4% fat		045	32	1	07		
5% fat		050	37	1	07		
6% fat		055	42	1	07		

Iodine: Add to meal rations 1% salt carrying 0 015% iodine
Cobalt: Use salt carrying 1 oz cobalt sulfate per 100 lbs
Copper Use salt carrying 1% copper sulfate per 100 lbs

TABLE 9-10 *Daily Nutrient Requirements for Swine*

	Description of Pigs									
							Breeding Stock			
	Market Stock						Pregnant females and breeding boars		Lactating females	
							Young stock	Adults	Gilts	Adults
Liveweight, lbs	25	50	100	150	200	250	300	500	350	450
Expected daily gain, lbs	0.8	1.2	1.6	1.8	1.8	1.8	0.75	0.5		
Total feed (air dry) lbs.	2.0	3.2	5.3	6.8	7.5	8.3	6.0	7.5	11.0	12.5
Total digestible nutrients (75% TDN) lbs	1.6*	2.4	4.0	5.1	5.6	6.2	4.5	5.6	8.3	9.4
Crude protein, lbs	0.36	0.51	0.74	0.88	0.90	1.00	0.90	1.05	1.65	1.75
Inorganic nutrients										
Calcium, gms.	7.3	9.4	15.6	17.0	18.7	20.7	16.3	20.4	30.0	34.0
Phosphorus, gms	5.4	6.5	10.8	10.2	11.2	12.4	10.9	13.6	20.0	22.7
Salt (NaCl), gms.	4.5	7.3	12.0	15.4	17.0	18.8	13.6	17.0	25.0	28.4
Vitamins										
Carotene, mg	0.5	1.0	2.0	3.0	4.0	5.0	15.0	18.7	27.5	31.2
Vitamin D, I U	180.0	288.0	477.0	612.0	675.0	747.0	540.0	675.0	990.0	1,125.0
Thiamine, mgs	1.0	1.6	2.6	3.4	3.8	4.2	3.0	3.8	5.5	6.2
Riboflavin, mgs.	2.4	3.2	5.3	6.8	7.5	8.3	7.2	9.0	13.2	15.0
Niacin, mgs.	16.0	19.2	26.5	34.0	37.5	41.5	30.0	37.5	55.0	62.5
Pantothenic acid, mgs.	10.0	16.0	23.8	30.6	33.8	37.4	27.0	33.8	49.5	56.2
Pyridoxine, mgs.	1.2	1.9								
Choline, mgs.	800.0									
Vitamin B_{12}, mcgs.	20.0	16.0	26.5							

* For young pigs a high energy diet (80% TDN) is recommended

TABLE 9-11 *Recommended Daily Nutrient Allowances for Beef Cattle, Based on Air-Dry (90% dry matter) Feed*

		Daily Allowances per Animal						
		Total Feed						
Body Weight, lbs	Expected Daily Gain, lbs	Per cent of Live weight	Per Animal, lbs	Digestible Protein, lbs	TDN, lbs	Calcium, gms	Phosphorus, gms	Carotene,* mgs
				Normal Growth Heifers and Steers				
400	1.6	3.0	12	0.9	7.0	20	15	24
600	1.4	2.7	16	0.9	8.5	18	15	36
800	1.2	2.4	19	0.9	9.5	16	15	48
1000	1.0	2.1	21	0.9	10.5	15	15	60
				Bulls, Growth and Maintenance (Moderate Activity)				
600	2.3	2.7	16	1.3†	10.0	24	18	36
880	1.7	2.1	17	1.4	11.0	23	18	48
1000	1.6	2.0	20	1.4	12.0	22	18	60
1200	1.4	1.8	22	1.4	13.0	21	18	72
1400	1.0	1.7	24	1.4	14.0	20	18	84
1600		1.6	26	1.4	14.0	18	18	96
1800		1.4	26	1.4	14.0	18	18	108
				Wintering Weanling Calves				
400	1.0	2.8	11	0.7	6.0	16	12	24
500	1.0	2.6	13	0.8	7.0	16	12	30
600	1.0	2.5	15	0.8	8.0	16	12	36
				Wintering Yearling Cattle				
600	1.0	2.7	16	0.8	8.0	16	12	36
700	1.0	2.4	17	0.8	8.5	16	12	42
800	0.7	2.3	18	0.8	9.0	16	12	48
900	0.5	2.0	18	0.8	9.0	16	12	54
				Wintering Pregnant Heifers (Weights are for beginning of winter period; gains average for period)				
700	1.5	2.9	20	0.9	10.0	18	16	42
800	1.3	2.3	20	0.9	10.0	18	16	48
900	0.8	2.0	18	0.8	9.0	16	15	54
1000	0.5	1.8	18	0.8	9.0	16	15	60

TABLE 9-11—*Continued*

		Daily Allowances per Animal						
		Total Feed						
Body Weight lbs	Expected Daily Gain lbs	Per cent of Live weight	Per Animal, lbs	Digestible Protein lbs	TDN, lbs	Calcium, gms	Phosphorus gms	Carotene,* mgs
Wintering Mature Pregnant Cows (Weights are for beginning of winter period, gains, average for period)								
800	1.5	2.8	22	1.0	11.0	22	18	48
900	1.0	2.2	20	0.9	10.0	18	16	54
1000	0.4	1.8	18	0.9	9.0	16	15	60
1100	0.2	1.6	18	0.8	9.0	16	15	66
1200	0.0	1.5	18	0.8	9.0	16	15	72
Cows Nursing Calves, 1st 3 to 4 Months After Parturition								
900-1100	None		28	1.4	14.0	30	24	300
Fattening Calves Finished as Short Yearlings								
400	Average for	3.0	12	1.1	8.0	20	15	24
500	period,	2.8	14	1.2	9.5	20	16	30
600	2.0 lbs	2.7	16	1.3	11.0	20	17	36
700	daily	2.6	18	1.4	12.0	20	18	42
800		2.5	20	1.5	13.5	20	18	48
900		2.3	21	1.5	14.5	20	18	54
Fattening Yearling Cattle								
600	Average for	3.0	18	1.3	11.5	20	17	36
700	period,	3.0	21	1.4	13.5	20	18	42
800	2.2 lbs	2.8	22	1.5	14.0	20	19	48
900	daily	2.7	24	1.6	15.5	20	20	54
1000		2.6	26	1.7	17.0	20	20	60
1100		2.4	27	1.7	17.5	20	20	66
Fattening Two-Year Old Cattle								
800	Average for	3.0	24	1.5	15.0	20	18	48
900	period,	2.9	26	1.6	16.0	20	20	54
1000	2.4 lbs.	2.7	27	1.7	17.0	20	20	60
1100	daily	2.6	29	1.8	18.0	20	20	66
1200		2.4	29	1.8	18.0	20	20	72

ing the latest *N.R.C. Standards for Dairy Cattle* (1955), for *Swine* (1953), and for *Beef Cattle* (1950).* They will be adequate for the calculation of working rations for these classes of stock, and will serve also to illustrate the modern conception of requirement tables.

SUGGESTED READING

A series of individual pamphlets published by The Committee on Animal Nutritioo, U.S. Natiooal Research Council, 2101 Constitution Ave., Washington 25, D.C.

Nutrient Requirements of Domestic Animals.

Poultry (1950).
Swine (1953).
Dairy Cattle (1955).
Beef Cattle (1950).
Sheep (1949).
Horses (1949).

Kellner, O., *The Scientific Feeding of Animals*, The Macmillan Company, New York (1913).

Kriss, Max., "A Comparison of Feeding Standards for Dairy Cows, with Special Reference to Energy Requirements," *J. Nut.*, V. 4, p. 141 (1931).

Morrison, F. B., *Feeds and Feeding* (21st Ed.), The Morrison Publishing Co., Ithaca, N.Y.

* The original pamphlets from which these tables were taken as well as those for other stock are available from the National Research Council, 2101 Constitution Avenue, N.W., Washington 25, D.C. U.S.A.

SUMMARY OF SECTION II

THIS SECTION has been an examination of feeding standards—those tables in which are recorded the quantities of certain nutrients that we believe should be provided in the rations of the animals of different feeding categories It should be evident that even the latest and most modern standards are incomplete as to the nutrient requirements The missing values are gradually being filled in as our knowledge increases, but even the data that are available must be used with judgment We must never forget that we are dealing with living animals in applied nutrition, and that their most obvious characteristic is their variability

This variation applies to the structure and functioning of every tissue Not only are two animals different, but the same animal differs functionally from one time to another Thus there is no way of describing accurately their nutrient requirements in fixed figures We must use averages, realizing that such quantities may not depict the needs of any one animal at any particular time These averages, however, work very well as guides for the formulation of meal mixtures suitable for groups of animals, since the variations of animals of a group from the average tend to be compensating

Fortunately the differences in the nutrient needs between animals, and also for one animal at different times, are correlated with differences in energy needs, so that by adjusting the daily allowances to an animal of total food according to appetite, or to size, or to production rate the adjustment for the nutrient need is also made

Were it not for this relation between the need for energy and that for the nutrients, the problems of feeding practice for herds and flocks would make anything like scientific rationing practically prohibitive.

The key place occupied by energy in the "operating needs" of an animal makes it especially important that our estimate of energy requirement should be as accurate as our knowledge will permit. For this reason we dealt critically with the problem of energy need. We must not assume, however, that our present beliefs regarding this requirement or that of any nutrient will not have to change as more of the facts are learned. This means obviously that feeding standards are not finalized, and are not likely to be for many years to come. They are nevertheless already indispensable guides to the formulation of workable rations even though we may expect gradually to learn how better to adjust the balance between the nutrients to meet more exactly the nutrient needs of our livestock, and hence to improve their performance.

Those who expect to prepare successful livestock rations must, therefore, use feeding standards, and use them properly. They are one of the basic "tools of the trade"; and it is as true here as with any other occupation, that the competence of the workman can be judged by his knowledge of and skill in the use of his tools.

SECTION III

THE NUTRITIONAL CHARACTERISTICS OF SOME COMMON FEEDS

The number of different feedstuffs used at one place or another in the feeding of livestock is large Morrison lists analyses for 173 dry roughages (not including grades of the same feed), 143 green roughages and roots, 46 silages, and 432 concentrates Schneider records the analyses and digestibility of some 2300 feedstuffs With such reference data readily available there is little reason to attempt here any extensive discussion of but a few key feeds The plan of this section is rather to discuss first the general nutritional properties of feeds belonging to one group (i e basal feeds, protein supplements, etc) We shall augment this discussion by considering in detail the characteristics of one or more key feeds in that subgroup Finally, we shall consider the unique properties of a selection of other common feeds belonging to the subgroup—properties that determine the extent to which they individually may replace the key feeds in rations, and the consequences of such substitutions

With a sound understanding af the general nutritional nature of the feeds comprising the several subgroups, together with enough description of a particular praduct to assign it correctly to its proper category in the classification and to disclose any pronounced peculiarity, we can incorporate feedstuffs that are not well-known into rations with reasonable assurance that they are used in a way to make the most of their potential feeding values, and to avoid major undesirable consequences of improper use

CHAPTER 10

A Classification of Feeds

FEEDS COMPOSED of naturally occurring products and of many of the by-products of the milling or other processing of such materials are, figuratively speaking, packages containing many, and perhaps usually most of the nutrients recognized as needed by animals. The amounts and proportions in which these operating necessities are present differ between feeds; and so, strictly speaking, no two feeds are nutritionally alike. But in the everyday practical formulation of rations, feeds of generally similar properties are considered as potential substitutes and exchanges are made within mixtures in accordance with market price, availability, and to some extent feeder preference, if such has been expressed. Thus it becomes expedient to establish categories of feeds within which substitutions are justified by similarity of nutritionally important properties.

Roughages and Concentrates

The first broad grouping of feeds is logically based on their physical nature as to bulkiness—a classification that separates products of relatively low from those of high concentration of energy-yielding nutrients. Such a grouping brings together, under the heading of roughages, the feeds that are essentially whole plants, such as, hay, straw, silage, pasture and roots; and groups all other feeds under the heading of concentrates. The physical differences between these two groups of feeds are such that we do not make substitutions in

the usual sense of the term between them The complete rations of herbivorous animals often include both roughage feeds and concentrate feeds In other cases only roughages are involved But con centrates alone will not provide suitable rations for such animals regardless of the nutrient assortment they contain

Subclassification by Protein Content

Within these two groupings, it is expedient to use crude protein content as the principal basis for the first subclassification, even though in the strict sense feed proteins are varying combinations of up to twenty or more nutrients (amino acids) The amino acid assortment in most feeds is a mixture that for purposes of feed substitution may be defined in total by the conventionally determined protein And, furthermore, the proportion of protein in a ration is nutritionally important in its own right Finally, the concentration of protein in a feed is often correlated with some of its other nutrient make-up or with its general nutritive properties

With roughages the protein subclassification is less exact than with the concentrates because the protein content of different samples of the same feed may vary enough to overlap two categories For example, legume hays on the average carry about 12%, and non-legume material 5% of protein But early cut Timothy, a non-legume grass, may have a higher protein than over-ripe clover, a legume

This situation is partly a consequence of inadequate description of roughage feeds For the majority of cases the protein level of the roughage part of the herbivores' ration rather than the specific kind of plants involved is of the greater significance in its proper use Quality of protein is of secondary importance Amount of total protein, however, is correlated with stage of maturity, of leafiness, and to a considerable degree, with the lignification of the forage The inadequacy of the plant name alone as indicative of feeding value of roughages is well recognized, but to date no really satisfactory descriptive scheme has been devised to replace the simple name or to amplify it

There are also anomalies among the concentrates. For example, in the classification we outline below the upper limit of protein of the basal feeds is set at 16%, but some samples of most of the cereal grains, excepting corn, may run well over this figure. Such cases do not vitiate the usefulness of the plan.

Insofar as a feed classification is concerned, there is no official or universally accepted grouping. The one presented herewith has been found useful for many years by the author and, consequently, quite naturally finds its way into this book.

Outline Classification of Feeds

A. Roughages

Feeds of low available energy per unit weight, usually because of high fiber, though sometimes because of high water content.

By regulation of the Canadian Feeding Stuffs Act, any feed carrying more than 18% crude fiber is a roughage in Canada. Thus, roughages in this sense include not only forages but such products as oat hulls, alfala meal, dried beet pulp, brewers' grains (some samples), rice bran, which are sometimes listed among the concentrates. Few roughages carry as much as 60%, and the average is not far from 50% TDN.

- I. Dry forages
  - a) Hays
    - 1. Legume
    - 2. Non-legume
  - b) Straws
  - c) Other products of more than 18% crude fiber.
- II. Succulent forages
  - a) Silages
    - 1. Corn
    - 2. Grass (Hay crop)
  - b) Pasturage
  - c) Roots and tubers

B. Concentrates

Feeds of high available energy per unit weight, usually because of high starch or oil or protein content and low fiber

Concentrate feeds normally carry more than 60% TDN and because of high fat may be rated at over 100% An average for the common concentrate feeds would be about 75%

I Basal Feeds (feeds of 16% protein or less)
II Protein Supplements (feeds of 20% protein or more)
  a) Feeds of plant origin
    1 20-30% protein
    2 30% or more of protein
  b) Feeds of animal or marine origin

C. Miscellaneous Feeding Materials

I Vitamin carriers
II Mineral element carriers
III Other (antibiotics, amino acids, etc)

Variability of Feedstuffs in Chemical Make-Up

As we have already mentioned, one of the purposes of a feed classification is to group together feeds of somewhat similar nutritional characteristics, thus defining products that are partial substitutes for each other Thus feeds legitimately included in the basal feed category may usually be interchanged, completely or in part, among themselves Normally feeds of the basal category would not be exchanged with feeds of the protein supplement category

However, even though feeds may be grouped together in categories of similar general nutritional properties it does not follow that different samples of the same feed will have the same chemical make up For example, different samples of shelled corn may run from 8 to 15% of crude protein, wheat from 9 to 19%, oats from 10 to 18%, etc This variability between samples is obviously a factor we must consider in feed substitution, assuming, of course, that the

chemical make-up of the feed bears an important relationship to its feeding value

During the past few years realization of the need for considering variation, not only in feeds but also in animals and their response to feeds, has become more general Actually very little mathematics is needed to understand the problem and to interpret the commonly used measures of variation, such as are applicable in this particular case

Perhaps the easiest way to make clear the problem of variation as it applies to some chemical component of a feed will be to cite an example, and one that is particularly applicable comes from Bulletin No 461 of the Texas Agricultural Experiment Station, in which is given the following tabulation of the distribution of 586 samples of cottonseed meal with respect to their analysis for crude fiber (see Table 10-1)

If we were to look in a table of feed composition for cottonseed meal we might find that the crude fiber was given as 11 3% for the average of all of these values Actually, however, it is evident that the crude fiber in different samples has run all the way from 6% to 15% Most of the samples, however, have come closer to the average—106 out of the total or about 18% of them are found in the 11 to 11 5% class Both below and above this point the samples become progressively fewer in number

If we were to plot the samples according to crude fiber class, we *would get a bell-shaped curve, which would approximate in shape* the normal frequency distribution curve A great many characteristics of biological material actually follow the so-called normal frequency distribution, and consequently, even though the observed figures do not fit exactly into this curve, the statistical constants which are calculated to describe the curve are used in measuring the variability actually found in distributions such as that shown above for crude fiber

Of these measures the standard deviation (S D) is the most common Without going into any consideration of how the S D is calculated we should merely explain at this point that it measures an interval above and below the average, within which we may expect

TABLE 10-1 *Distribution of 586 Samples of Cottonseed Meal as to Crude Fiber Content**

Crude fiber class %	Number of samples in each class	% of total samples in each fiber class	
6 0	2	34	
6.5	0	0	
7 0	2	34	
7.5	5	85	
8 0	8	1.37	25.5% below −1 S D
8.5	15	2.56	
9 0	25	4 27	
9.5	55	9 37	
10 0	73	12.46	
10.5	102	17.41	
11 0	106	18 09	
11.5	80	13 65	68% within ±1 S D
12 0	55	9.39	
12.5	22	3.75	
13.0	22	3.75	
14.0	4	68	
14.5	0	0	6.5% above +1 S.D
15 0	2	34	
Total	586	Total 100%	
Av	11.29		
S D	±1 26		
C V	±11%		

* Texas Bulletin 461

approximately two-thirds of the samples to fall, with one-sixth of them being above the upper limit and one-sixth of them below the lower limit of this interval Obviously, therefore, if we pick at random any one of the samples in the whole population we are considering, our chances of finding that it lies within the limits of ± one S D are two out of three, and this result is referred to as odds of two out of three, or is noted as P = 33, meaning that the chance of *not* finding the value within ±1 S D is 33%

Coming back to the figures in Table 10-1, we may find it interesting to see where the S.D. of the array of crude fiber values actually falls. The calculated S.D. of the per cent of crude fiber is ± 1.26 units of per cent. Consequently, we should expect two-thirds of the values to fall between the midpoint of the 10% class and the midpoint of the 12.5% class (i.e., $11.29 - 1.26 = 10$; $11.29 + 1.26 = 12.5$). If we make such a division (last column of the table), we find that approximately 68% of all of the samples fall within the limits of ± 1 S.D. from the mean. As it happens only 6.5% of the samples have more crude fiber than the upper limit of the S.D., and 25% have less than the 10%. This degree of "goodness to fit" in practice as compared to theory, is to be expected where small numbers are involved. One may think that 500 samples is not a small number, but it is small as compared to an infinite population on which the normal frequency curve is based. The important thing here, however, is that about two-thirds of the samples actually fall between + and -1 S.D. from the mean.

Thus, the probable crude fiber content of cottonseed meal can be described very simply by saying that it averages 11.29% and that two-thirds of all the values will likely fall between 11.29 ± 1.26 units of per cent. Thus about two samples out of three, if picked at random, will be expected to have somewhere between 10 and 12.5% of crude fiber.

It is sometimes useful in comparing the degree of variability to express the S.D. as a percentage of the mean, which gives a measure of the variability that is directly comparable between sets of figures whose means are not the same. In the example cited above the variability of crude fiber in cottonseed meal turns out to be 11% ($1.26 \times 100 \div 11.29 = 11.15\%$). This figure is useful in predicting the probable variation in crude fiber of cottonseed meals whose average is not 11.29% but perhaps, because of some process change, might be only 8%.

If, in addition to samples of the same feed, we examine a reasonably large number of samples of feeds of the same category, we may be able to establish a typical variability for the crude fiber of feeds in general. In fact, data from this Texas bulletin show that the

coefficient of variation of crude fiber between different samples of the feeds for a considerable number of different concentrate feeds is actually about 12% The coefficient will be somewhat larger for feeds that are very low in crude fiber, and somewhat smaller for feeds that are high in crude fiber This difference is merely an arithmetical effect together with the fact that errors of chemical determination of crude fiber are likely to increase with samples that carry very small quantities of crude fiber merely because of the difficulties of manipulation under routine analytical conditions For most practical purposes of feed substitution we can use an *average coefficient of variation* in the proximate analysis of feeds as usefully as we can the coefficient of variation calculated specifically for each feed separately This observation applies whether it is protein, fat, fiber, or nitrogen free extract with which we are concerned

We must mention one further thing concerning the coefficient of variation or the S D By definition ±1 S D includes two-thirds of the variates in the population under consideration, and, consequently, the chance that any one variate picked at random will fall within these limits is two out of three It can be shown mathematically that if the S D is multiplied by two (so that the limits set are now 2 S D above and below the mean) this interval will include 95% of the variates of the population Consequently, for any single variate, picked at random the chances will be 95 in 100 or 19 out of 20 that the value will fall within these larger limits These limits of ±2 S D are sometimes referred to as the fiducial limits, and they define an interval within which we shall with practical certainty expect to find all but 5% of the individual values

Unfortunately there are few data available on the normal variability of the proximate principles of feedstuffs Probably, however, from what figures we can find we may expect that the variability in analysis between samples of the same feed will be measured by coefficients of variability about as follows

Protein	± 8%
Ether extract	±15%
Crude fiber	±12%
Nitrogen free extract	± 3%

Taking these figures we can calculate the probable fiducial limits of the composition as to protein, fat, fiber, and nitrogen-free extract of feeds according to the average per cent composition they carry. This has been done in Table 10-2.

In this table the first column gives percentage figures ranging from 2 to 90. Some of these figures are in bold face type. The 4%, for example, will be close to the average fat content of most con-

TABLE 10-2 *"Normal" Variability in Proximate Analysis of Concentrate Feeds*

Proximate Principle in Feed (%)	Probable Fiducial Limits ($P = 0.05$) for Concentrate Feeds in			
	% protein C.V. = 8	% fat C.V. = 15	% fiber C.V. = 12	% N.-free extract C.V. = 3
1		0.7-1.3		
2				
4		2.8-5.2	3-5	
6				
8			6-10	
10				
12	10-14*	8-16	9-15	
14				
16				
18				
20				
25	21-29			
30				
35				
40	34-46			37-43
45				
50				
60				
70	59-81			65-74
80				
90				

* $12 \times (\pm 8 \times 2) = \pm 1.9$ or a range between 10.1 and 13.9

centrate feeds 12% is typical of the average protein content of the basal feeds, while 25% will fit the protein content of the vegetable low-protein supplements, and 40% that of the higher protein category 70% is not far from the typical nitrogen-free extract figure for most of the cereal grains and low protein concentrates In columns 2, 3, 4, and 5 are shown the fiducial limits within which we can be reasonably sure the protein, fat, fiber, or nitrogen-free extract values of any particular samples will fall according to the average figure for that feed given in tables of proximate composition Thus, for the basal feeds, we can probably count on most samples of feeds belonging in this category to carry between 10 and 14% of protein However, for protein supplements such as brewers' grains and gluten feeds, where the average protein content is likely to be about 25%, we shall have to expect that different samples may range from about 21-29%

We may not realize the full significance of this problem of variability in composition until we deal with the problem of feed formulation in a later section of this book Nevertheless, in the discussions that follow in the next two or three chapters concerning feedstuffs, you will note that the composition figures given represent *averages,* and since no data on the variability from these averages is ordinarily available, the figures in Table 10-2 may assist in a better understanding of how nearly identical feeds known by the same name are likely to be

Before leaving this matter we should draw attention to a further interpretation of the variability figures that may be applicable to feeds within any one group As we shall see shortly a typical basal feed is defined as one that carries about 12% of crude protein On the other hand, basal feeds by classification definition also include all feeds carrying less than 16% protein Thus, because of the second definition, molasses, which carries only about 3% protein, still falls in the basal feed category

While it is quite common to examine the homogeneity of a population on the basis that observations which fall outside ± three times the S D do not belong in the category, this practice cannot legitimately be applied to the feed classification The feed classification

is not a biological classification but is one for convenience in feed manipulation Consequently, we cannot legitimately use S D as a final test of whether or not a given product belongs in a certain subclassification Perhaps what we should say is that a typical basal feed will carry between 10 and 14% protein and consider that samples of basal feeds which are outside this limit but still within the category are abnormal samples or are special cases Thus, wheat that carries 19% of protein is a special case of a basal feed that falls outside the expected range of basal feeds On the other hand, molasses is a product that is a low-protein concentrate and, consequently, by that definition is still a basal feed regardless of its exceedingly low protein content

Finally, we must realize that substitutions between feeds that differ in composition, such as in fiber or protein content, do not alter the average composition to the full extent of the difference between the two feeds substituted For example, if we have five feeds mixed in equal proportions and analyzing individually 10, 11, 12, 13, and 14% of crude protein, and we replace the one analyzing 10% protein by one carrying 14% protein, we shall change the average protein content of the mix only from 12 to 13% Similarly, if we introduce a second feed of 10% protein and delete one carrying 12% protein, we shall have dropped the protein average of the mixture by about ½% Thus, it is only where feeds of markedly different composition are exchanged in major proportions that we affect the average composition of the mixture sufficiently to be detectable in feeding value Again, we shall discuss this problem in its application when we consider ration formulation and feed substitution

PROBLEMS

1 Using Schneider's *Feeds of the World* regroup the non-roughage feeds into the appropriate categories of the feed classification Calculate the average protein, fat, and fiber content by categories How many feeds fall outside the fiducial limits suggested in this chapter?

2 What are the minimum and maximum limits found between feedstuffs that are called by the same name?

3 Does the variation in composition of roughages of the same name exceed that of different samples of the same concentrate feed Can you suggest a reason for your findings?

SUGGESTED READING

Fraps, G S, *The Composition and Utilization of Texas Feeding Stuffs*, Texas Agr Exp Sta Bull 461 (1932).

CHAPTER 11

Basal Feeds

ACCORDING to the notation in the Outline Classification, basal feeds are low protein concentrates. The upper limit with respect to protein is conveniently set at 16%, because this figure, then, includes wheat bran, which is otherwise difficult to classify. However, it is the entire seed of the cereals that is the typical basal feed. If we take an average of the protein, fat, fiber, TDN, Ca, and P figures for the six common grains, barley, corn, milo, oats, rye, and wheat, we shall have a workable chemical description of a basal feed in terms of those nutrients and proximate principles most useful in determining its proper place in a livestock ration. Such data are shown in Table 11-1.

Chemical Characteristics

Protein. From this table it will be seen that a basal feed is likely to carry about 12% crude protein of which between 75 and 80% is digestible. (Throughout this book *digestible* refers to *apparent digestibility* unless otherwise stated.) It is interesting to know that the average crude protein of the variety of mixtures of basal feeds actually found in Canadian commercially prepared ready-to-feed rations averages just about 12%, and for the rough calculation of the protein of a Canadian meal mixture it is customary to lump together the basal feeds at a protein of 12%. But for rations based largely on corn, this short cut is not justifiable.

TABLE 11-1 *Typical Composition of Cereal Grains (all figures are %)*

Basal feeds	Crude Protein Total	Crude Protein Digestible	Crude Protein Chemical score	Crude fat	Carbohydrates Crude fiber	Carbohydrates N free extract	Usually used value for TDN Cattle	Usually used value for TDN Swine	Calcium	Phosphorus
Barley	12.5	11.0	20	2.4	6.2	68	71	70	0.05	0.38
Corn	9.7	7.4	28	4.0	2.3	68	80	80	0.01	0.28
Milo	11.3	8.8		2.9	2.2	71	80		0.03	0.27
Oats	12.4	9.7	46	4.8	11.0	60	66	65	0.09	0.33
Rye	12.6	10.0	50	1.7	2.4	71	76		0.04	0.16
Wheat	14.6	10.8	37	2.1	4.1	70	83	80	0.03	0.43
An average basal feed	12.3	9.7		3.3	5.9	67	75	74	0.05	0.36

NOTE: The TDN values for these feeds will vary according to the quality of the samples.

In practice, one will not go far astray by assuming the basal feed mixture protein as 75% digestible

The quality of the protein of basal feeds is uniformly low as measured by any scheme that rates biological value numerically Of significance in this regard is the fact that as compared to egg protein all feeds of this group show lysine as their first limiting amino acid This knowledge is of importance in the choice of a protein supplement to be used in a 'balanced' ration It also explains why substitution between basal feeds is not likely to alter appreciably the protein quality of the mixture

Fat. The cereal grains belonging to the basal feeds normally carry from 2 to 5% of ether extract, but in a few instances there are by product feedstuffs that carry up to 13% of fat as in rice feed the mill run by product of the manufacture of polished rice Oat groats carry 7 or 8% of fat, as does hominy feed The fat of non-oily seeds

is concentrated in the germ, and any processing that removes an appreciable proportion of the protein and/or carbohydrate, but not the oil, will leave a by-product of higher fat content than that of the parent seed A knowledge of the processing involved in the production of a by-product feed is often helpful in understanding the feeding properties of such a product The official definition of feeds may partially define the processing of by-products

We can see an example of the effect of milling on the fat (and protein) of the by-products in corn By a series of cracking and sifting operations a granular corn meal is produced for human use The material that is too fine for the table corn meal or table hominy, together with all of the bran and as much of the germ as separates out, is combined into hominy feed Thus, the germ is concentrated in the hominy feed with a consequent increase in its fat The increase in germ protein is counteracted by the increase in the corn bran so that the protein of hominy is slightly lower than that of corn, while the crude fiber content is raised

The production of starch, on the other hand, involves a wet milling process The corn grain, after being softened with warm water, and slightly acidified, is partly macerated and then allowed to soak in water in large tanks The germs, because of their oil content, float to the top where they are removed, defatted, and dried into corn germ meal The residue from the germ separation is reground and sifted to remove the hulls, bran, tip cap, and other fibrous material The gluten and starch are removed from the remaining mass in suspension and later separated centrifugally The coarse residue made up of hulls, bran, etc is combined with the defatted germ, and to this base is added enough gluten to give a product of 23% protein in one case and one of 40% protein in another The former is gluten feed, the latter gluten meal Thus, removal of most of the corn oil results in two by-products of lower fat content than that found in the original corn, but of higher protein level, due to the separation and removal of the starch of the corn grain

The wet-milling steps are illustrated in Fig 11-1

Of course, not all plant seeds are processed in this manner, but

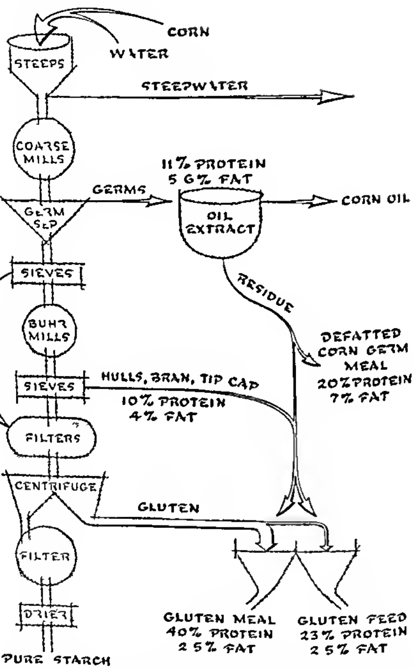

Fig 11 1 *Diagrammatic plan of wet milling of corn to produce starch (By products with their approximate protein and fat contents are also shown)*

the principle of the nature of the by-products is the same Remove carbohydrate, or fat, or protein, and the residue will be higher than in the parent material in the remaining fractions

Ash. Basal feeds never show concentrations of calcium high enough to meet the needs of animals, and, consequently, they are not depended on as Ca sources Indeed, in practice, they are often neglected in making calculations for calcium supplementation The content of phosphorus, on the other hand, is such that for some classes of pigs, and sometimes with cattle and sheep also, there is no need for special supplements However, much depends on the kind and amount of roughage also fed to herbivorous species, whether or not supplemental phosphorus is needed The usual rule is that pig rations need calcium, while cattle rations need phosphorus fortification

Carbohydrates. As we should expect, the fraction of basal feeds of primary nutritional concern is the carbohydrate About two-thirds of the weight of the seed is likely to be starch, which will usually be about 95% digested This high concentration of easily digested carbo hydrate is not only the distinguishing feature of basal feeds, but variation in this characteristic is responsible for the consequences of substitutions of feeds of this category

Crude Fiber. The average crude fiber of the basal feeds is about 6%, but individual feeds are subject to considerable variation in this fraction In this book the upper limit for concentrates is taken as 18%, partly because in Canada by legal definition feeds over 18% fiber must be registered as roughages In particular, the coarse grains (barley and oats) may show wide deviations in fiber from sample to sample, due ordinarily either to an increase in hull or to a decrease in the starch filling of the groat Differences in fiber affect markedly their available energy value and hence their relative feeding value Indeed, the most important consequence of substitution between basal feeds is usually traceable to differences in the crude fiber of the products exchanged Fibers of different origin are often quite dif-

ferent nutritionally The tabulation in Table 11-2 from Morrison's *Feeds and Feeding* is instructive

TABLE 11-2 *Digestibility of Crude Fiber*

Crude fiber from	% digestibility
Wheat	90
Wheat bran	53
Wheat shorts	60
Oats	38
Rolled oats	80
Oat clippings	63
Oat hulls	40
Barley	56
Barley feed	38
Brewers grains	49
Malt sprouts	87
Flaxseed	60
Linseed oilmeal o p	59
Linseed oilmeal solvent	74
Soybeans	37
Soybean oilmeal	68
Corn	57
Corn bran	72
Corn gluten feed	92
Corn oilmeal	75
Corn distillers grains	83

If the variation shown in Table 11-2 is all traceable to the uncertainties of the chemical procedure for this feed fraction then the determination is of little use However, taking the published data we find much food for thought For example, the crude fiber of wheat, shorts, and bran is presumably the same material, though in digestibility the range is from 53 to 90% (wheat, 90%, shorts, 60%, bran, 53%) Similarly, that of oats, oat clippings, rolled oats, and oat hulls range from 38 to 80% (oats, 38%, clippings, 63%,

rolled, 80%; hulls, 40%). It seems probable that processing that involves soaking improves the digestibility of the fiber. The digestibility of the fiber of corn grain is 57%, but that of corn bran, corn gluten feed, corn oilmeal, and corn distillers' grains ranges from 72 to 92%, with an average of 80%. Solvent extraction appears to have improved the digestibility of the fiber of flaxseed and of soybeans—flaxseed, 60%; linseed oilmeal, old process, 59%; solvent extraction, 74%; soybeans, 38%; soybean oilmeal (solvent), 68%.

These data are from ruminant digestion trials and may be too high for omnivora, but regardless of species of animal, any part of the apparent utilization of the fiber of these feeds that is not chemical error is a consequence of attack by digestive system microflora. One might argue that unprocessed fiber of seeds, which in its natural setting represents an outer protective coating of the seed, is relatively resistant to bacterial attack. This resistance may be due to lignification and/or to waxy, horny, or other weather resistant coatings. In the milling or the wet processing of such seeds, some of these coatings may be partially disintegrated or dissolved, thus exposing the cellulose to easy attack by microorganisms of the digestive system. "Digested" crude fiber, of course, yields as much energy to the animal as starch.

Whatever the true explanation, it is easily demonstrated in feeding trials that fibers of different origin may affect the feeding value of a ration quite differently. Add 25% wheat bran to a fattening hog ration, and the rate of gain is depressed. Add malt sprouts to an equal fiber level and feed intake is increased, and the gain of the pig is enhanced. Add barley hulls, and the acceptability of the ration is damaged.

Thus, while we may not be able to predict the reaction of the animals to change in the source of crude fiber in a ration; we can usually trace the important changes in the feeding value of a ration due to basal feed substitution, directly or indirectly, to the crude fiber involved. It is also generally true that amount of fiber and of available energy of basal feeds or feed mixtures are positively correlated. Thus, raising the fiber level means greater bulkiness and lower available energy, which in turn demand higher feeding levels.

In other words, high fiber feeds are relatively less efficient sources of productive energy

Non-chemical Characteristics of Basal Feeds

Bulk. In a general consideration of characteristics of basal feeds as a group there are in addition to the few chemical items some others we should mention The first one in order of importance may well be bulkiness

It is true, of course, that all the ingredients contribute to the final weight of a feed mixture per unit of its volume But since basal feeds normally constitute more than half the total ingredients of "balanced" meal rations, they influence the ration in this respect more than the other individual components

Bulk is variously defined, but all definitions eventually mean that per unit of volume (i e , per quart or per bushel) a bulky feed is relatively low in its yield of biologically available energy We can usually assume safely that among basal feeds TDN is positively correlated with weight per quart (or other volume measure) The reason for this relationship is ordinarily traceable to the level of fiber in the feed, because crude fiber of the four potential energy-yielding fractions is likely to be the least digestible We get an idea of the situation from examination of a few typical basal feeds, though we can make quantitative interpretation of the figures only in general terms for two reasons Figures for weight per quart of ground basal feeds are subject to considerable error because of the difficulty in controlling the degree of packing of the feed when filling the measure, and second, values for the TDN of specific feeds are not constants being modified by species of animal, by the nature of the crude fiber, and by whether the digestibility figures are determined directly or indirectly In Table 11-3 we present typical data for TDN, weight per quart, and per cent of crude fiber of a few of the more common basal feeds Fig 11-2 following shows the trends of these relationships graphically

As we can see from these data there is a pronounced tendency for an *increase* of one percentage unit in crude fiber or of 0 12 lb

TABLE 11-3 *Relation of TDN, Wt./Qt., and per Cent of Fiber in Some Ground Basal Feeds*

Feed	TDN (swine)	Lb./qt.	% fiber
Wheat	80	1.7	4
Corn	80	1.5	2
Rye	75	1.5	2
Barley	70	1.1	6
Oats	65	0.7	10
Standard Middlings	64	0.8	7
Wheat Bran	57	0.5	9
Oat Mill Feed	23	0.3	27

decrease in weight per quart of a basal feed to be associated with a *decrease* of about 2.5 percentage units in TDN. The degree to which these trends will hold for individual feeds is dependent to some extent on the fat content, since fat is relatively light in weight for its digestible energy value.

The significance of these relationships lies in the consequences of substitutions between basal feeds in a meal mixture formulation. Obviously the use in a meal mixture of a bulky feed in exchange for a heavier one will mean a lowering of the TDN of the mixture; and, consequently, it will require a larger quantity of the new mixture to meet the total energy needs of an animal.

Put into other terms, bulky feeds are less efficient when we measure efficiency as feed required per unit of gain for an animal or for his production. This way of thinking about feeds, however, may lead to misconceptions, for it does not follow that feeds of relatively low efficiency (when efficiency is defined as above) are for that reason always less useful in animal feeding. There are many circumstances in which a light bulky feed or ration is to be preferred to a heavier more concentrated one, as, for example, in wintering idle adult stock, or in the production of lean bacon.

Animals are so constructed that simple restriction of total feed allowance has undesirable effects on their behavior. They are continuously hungry and hence restless and perhaps irritable. If they are

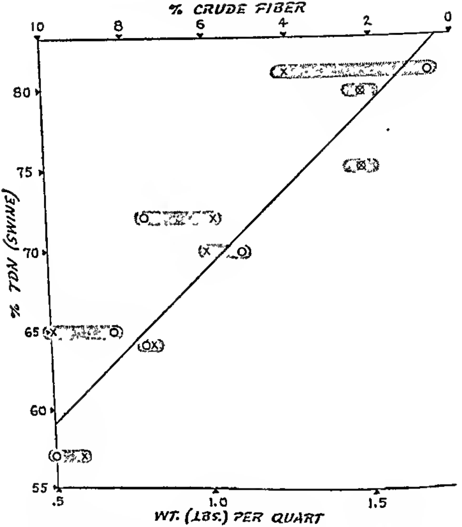

Fig. 11-2. *Relation among weight per quart, per cent of crude fiber, and the TDN of swine feeds.*

in groups, feed restriction leads to fighting for food and to the uneven distribution of the limited supply between the more aggressive and the timid individuals. The stockman's way of solving this management problem is often to feed a light bulky feed in quantities sufficient to satisfy appetite, but at the same time to restrict the intake of TDN as desired. Thus, wheat bran, alfalfa meal, oat feed, etc. are sometimes deliberately incorporated in a mixture because of their low

available energy. Such rations can be self-fed without the undesirable consequences of heavy intakes of more concentrated rations.

The more serious case is where cost of feed vs. cost of TDN is involved. Ordinarily bulky feeds are offered for sale at lower prices per ton than are the heavier more fattening basal feeds. If the price is in proper relation to the TDN it may matter little which feed is used. The increased quantity of feed needed to supply the available energy will be balanced by its lower cost per pound. Unfortunately, feeders may not have the data necessary to determine the equivalent values. Indeed, for many samples of feed, no data may be available.

For example, oats is a basal feed, which, because of variety, dates of seeding, and the seasonal growing conditions, may vary in weight per bushel from 24 to over 40 lbs. per bushel. Corresponding TDN values might range from 60% to 75%. Using these values a feeder would require just over two bushels of the light weight oats to supply the TDN of one bushel of the heavy sample. The lighter grain would be worth only half as much per bushel or only 80% as much per ton as the heavier. But, except for average or standard grades of grain, there is no information as to TDN values, since each sample will have a characteristic value of its own. In such cases the graph in Fig. 11-2 might help in making some sort of an estimate of relative values.

The problem of bulkiness of feeds arises again in the feeding of very young animals where, because of limited gastric capacity, an animal cannot consume enough of a bulky feed to meet its energy needs for the rate of growth desired. In this connection we might point out that skimmed milk is also a bulky feed though not because of relatively indigestible fiber, but because of the high content of water, which contains no energy. Where young animals that normally would be depending on milk are, for whatever reason, changed to milk substitutes, it is not desirable to make the ration into a water gruel because of the dilution of the energy value of the ration by the water. In fluid milk the energy value is maintained by its fat component. High fat in a man-made ration, however, is often a liability because of its unstable nature. Experiments with puppies weaned at 2 weeks, guinea pigs at 2 days, pigs at 10 days, and calves

at 2 weeks, all show that self-fed, dry, low-fat rations can permit as rapid gains in body weight and be nutritionally as satisfactory as liquid milk in all other ways Fresh water, of course, must be freely available when dry rations are fed, and the nutrient make up of the diet must be adequate When such rations are fed as a water gruel, the progress of the young is less satisfactory unless enough fat is incorporated to maintain, in spite of the water dilution, the energy level equal to that of the dry meal

Quality in Basal Feeds

The matter of sample-to-sample variation in quality is a special problem with basal feeds The important feeds of this group fall into two subgroups on a crude fiber basis Corn, wheat, and rye represent a type of plant seed that is without an enveloping hull Barley and oat kernels, on the other hand, after threshing, remain encased in their flowering glumes, and because of this attribute, they are referred to by the Trade as *coarse grains*

Because of this division of basal feeds it may be helpful in considering quality to discuss in some detail the characteristics that give various basal feeds their special nutritional properties or that require consideration in making substitutions in ration formulation

Corn (Maize)

Of the basal feeds of the low fiber group corn is the key feed in livestock rationing As seen in the tabulation following (Table 11-4) it is the lowest in crude protein and highest in available energy

We might also point out that under favorable conditions of growth, an acre will produce as TDN about twice the total food value in corn as in any other cereal grain This high production is an economic consideration and makes it clear why corn is so important a crop in areas having climatic conditions favorable for its growth

From the standpoint of its nutritional properties corn cannot be

TABLE 11-4 *Relative Value of Basal Feeds as "Carbonaceous Concentrates"*

Grain	Protein (Morrison)	Net energy (Morrison)	Total feed value (Kellner)
Corn (maize)	67	100	100
Barley	96	86	98
Kafir	83	93	—
Milo	85	93	—
Oats	91	88	95
Rye	96	86	97
Wheat	100	97	95

dealt with so simply. Corn, like all other grains, is subject to variation in make-up as a consequence of varietal differences and because of the specific conditions under which it is grown and harvested. Thus locally produced samples may differ from published average figures for chemical composition.

Perhaps the best recent information as to what corn grain is, as described by the chemist, is to be had from "A Survey of Corn Grain in the United States" which was undertaken by the Committee on Feed Composition of the U.S. National Research Council and published in their Report No. 1, issued in September, 1947.

In order to cover different climatic and soil conditions the U.S. was divided into ten districts and samples obtained from each, roughly on the basis of total production. The samples were taken by State Agriculturists and were examined for 25 different nutrients, which included proximate, mineral, and vitamin analyses. The result of the statistical study has never been published; but there are, nevertheless, average data available which permit a rather comprehensive picture of corn as a source of food nutrients. In Table 11-5 the average as well as the minimum and maximum values are given for 24 nutrients, all expressed on a 15% moisture basis.

The figures for the make-up of corn may be more meaningful if we look at them in relation to the recommended concentration of their

TABLE 11-5 *Nutrient Composition of Corn (Maize) Grain (15% moisture basis)*

Nutr ent		Mean	Minimum	Maximum	Recommended In rat on of 100 lb p g
Gross energy Cals		3.78	3.75	4 22	
Prote n	%	8 6	8 2	10 9	16
Ether extract		3 9	3.7	5 8	
F ber		2 0	1 9	2 1	
N trogen-free Extract		69.3	68 6	69.5	
Ash	%	1 2			
Calc um		023	014	029	65
Phosphorus		268	23	.32	.45
Potass um		.27	15	37	
Iron		0023	0017	0028	15 0
Magnes um		10	09	12	
Sod um		010	0008	028	
Chlor ne		058	048	065	
Iod ne		00006			0022
Fluor ne		00006			
Manganese	mg /lb	2 5	1.5	3.7	18 0
Copper		1 8	.5	3 9	2 0
Cobalt		05	01	23	
V tam n A	I u /lb	3289	2780	3764	800
Th am ne	mg /lb	1 8	1.5	2 0	0.5
N ac n		10 9	8 2	17 1	5 0
Riboflav n		0.5	0 5	0 6	0 8
Pantothenic Acid		2 1	1 9	2 5	4.5
Fol c ac d		04	03	04	

nutrients in a market pig meal mixture Of course the comparisons must be general, because rations for other classes of stock will differ from those of a market pig

We can see at once that if corn is introduced into a balanced market pig ration it will lower the protein calcium phosphorus manganese, and niacin Though not shown in these data it is generally recognized that the quality of protein in coro will not meet non-

herbivor needs When corn is used for cattle or sheep feeding the calcium and sometimes the phosphorus may be adequately provided by the roughage, and the quality of protein is, of course, not an important factor

But as a source of energy, regardless of how one chooses to measure it, *corn stands at the top among the basal feeds* For cattle feeding, other perhaps, than for adult breeding stock, the feeding problem we meet most commonly is how to provide enough energy to permit growth, production, or fattening The common deficiency of roughage is low energy, and thus the high energy value of corn is of special value, since relatively small allowances will provide the quantities needed (as compared to other basal feed and more especially compared to the coarse grains) to balance the ration

High energy may be a liability This high energy, however, may not always be a blessing, for there are situations where the animal or the product may be subject to damage by rations of high energy

For market hog feeding the high energy value of corn grain will, under full or self-feeding, produce a carcass carrying more fat than is desired for so-called "lean" bacon The rashers from corn-fed carcasses are also likely to be of smaller "eye of lean," as has been shown in experiments at Macdonald College (see Fig 11-3) This over-finish is merely because the more rapid gains in weight have brought the pigs to market weight at younger ages and hence with less muscle development than would be found on older pigs

As we might expect from their nutrient makeup, wheat shows the same tendency as corn to fatten, while oats, carrying five or six times as much crude fiber and about 20% less TDN (for swine) produces a bacon rasher with 40% more lean and a 50% larger "pork chop" eye of lean

To those who are accustomed to raise and/or to use the coarse grains (barley and oats) corn and wheat are frequently regarded as uniform products This impression is doubtless gained from the relatively low variation in the weight per measured bushel and in the crude fiber of these two grains

It may be in order here to comment on the weight per bushel of grains In the feed trade a bushel of grain is not actually weighed

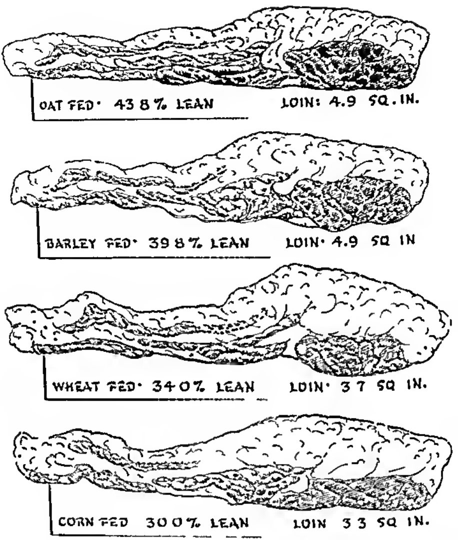

Fig 11-3 *Typical bacon rasher pattern taken between 3rd and 4th lumbar vertebrae and illustrating the effect of high energy feeds on leanness of bacon* (*Data from Macdonald College*)

to establish a basis for selling or buying the product Legal weights per bushel have been established—at values near the average for a given grain—and these are used in arriving at the monetary value for a given weight of grain, because by custom the price quoted by grain brokers is not per pound but per bushel A carload of 30 tons of oats would actually contain 1500 measured bushels of 40 lb oats

or 2000 bushels of 30-lb. grain. It would, however, be billed as 1765 bushels (34 lbs. per bushel Canadian standard for oats) at, say, $1.20 per bushel. Thus weight per measured bushel, often used as an index of relative energy value of a grain, must not be confused with the legal weight per bushel used in the grain trade.

To come back to variation in grains, a recent survey showed that individual "crops" of oats ranged from 15 to 50 lbs. per measured bushel. No such range of values is expected with corn. Insofar as fiber is concerned the U.S. survey of corn showed a range of from 1.9 to 2.1%. This range may be compared with data for the fiber given by Winton for the United States of:

	Minimum	Maximum
Barley	3.9	9.0
Oats	8.5	20.0

Similarly, the protein of corn is of relatively low variability, ranging essentially from 8 to 11%, while "crops" of the coarse grains will be found with as little as 8% and as much as 20% of crude protein, calculated as N × 6.25. Nevertheless, economically the range in protein levels in corn may be highly important.

In the compounding of batches of "balanced rations" the differences in the proportion of protein supplement needed, with low vs. high protein corn, to prepare a mixture of some desired protein level, may be large. Assume a ration is to be compounded with corn as the basal feed plus a mixed protein-mineral supplement carrying 35% of protein, and that a final mix of 15% protein is wanted. We calculate as follows:

Case I

Corn	8% protein		20 parts corn
	desired	15%	
Supplement	35% protein		7 parts supplement = 25% of mix.

Case II

Corn	11% protein	20 parts corn
	desired 15%	
Supplement	35% protein	4 parts supplement = 17% of mix.

Thus it is easy to understand the concern, in corn using areas, about the protein level of this grain

This situation may be quite different when wheat or the coarse grains are to be used Here it is not uncommon to find samples that already carry more protein than is needed in the completed ration The protein supplementation then is one of enhancing the quality of protein, and the amounts used are often the minimum to provide 10% of the final ration protein from an animal or marine source Thus for 1000 lbs of a 15% protein mixture it might be desired that 15 lbs of the protein should come from fishmeal This proportion would call for the use of about 21 lbs of fishmeal, and if the grain already carried 14% protein, the result would be a mixture of 16% protein

Low proteins of corn The generalization from these considerations is not only that corn, because of its typically low protein content, requires more protein supplementation than coarse grains or wheat, but perhaps more important, that but few livestock rations carrying the protein demanded by feeding standards can be made with corn *without* protein supplementation This is contrary to the case with average barley, oats, or wheat where for herbivora there is no need of protein additions to the farm grain if roughage of reasonable quality is also fed

Two other characteristics of corn should be mentioned The one concerns its fat (or ether extract) content, which is higher than the average of basal feeds This is both an asset and a liability There is little doubt that a part of the acceptability of corn to animals is traceable to its fat component, not specifically because of corn oil, but rather because of the effect of the fat on the physical nature of the

ground grain Ground corn is not dusty, and unless ground to an abnormally fine modulus does not become pasty with mastication While there is no direct proof that the high palatability of corn to all classes of stock is traceable to the fat, it is probably significant that in feeding studies at Macdonald College the addition of about 5% of a vegetable oil improves the acceptability of dry low-fat diets for young pigs, puppies, and guinea pigs Without the oil the rations carried about 2% ether extract That the oil did not improve the diets otherwise is evidenced by the fact that they were no more efficient per calorie in producing weight gains than the low-fat mixtures

The high fat level, however, has a distinct liability, since ground corn goes rancid easily The effect may be slight and represent merely a superficial loss of palatability or it may be extensive enough to result in heating and/or molding with the attending adverse effects on nutritive value In general, ground corn cannot be stored without risk of such damage

Finally, we should note the problem of moisture content, though the general significance of the water content of feeds has already been discussed Samples of corn as harvested are likely to vary more in water content than those of any other grain They may range from 8% water with fully mature material to as high as 35% in the case of frosted immature grain Ear corn carrying over 25% and shelled corn carrying more than about 15% water will not store without damage in the usual types of cribs or bins Aside from the effect of moisture content on storage, the nutritive value of the grain will decline as it is "diluted" with more and more water (see page 29)

The Coarse Grains

As we have already implied, it is the glume or hull that accounts for the higher fiber of the so-called coarse grains, as is clearly shown in Table 11-6, giving the pertinent data for barley and for oats

The cause of the difficulty with these grains is that the proportions of groat to hulls are subject to wide variation due to variety, modi-

TABLE 11-6 *Proximate Composition of Hull vs the Groat of Oats and Barley*

Feed	Crude protein	Fat	Fiber	TDN (ruminant)	Approx. wt. per quart
	%	%	%	%	lbs
Oat grain	12.6	5.2	8.9	72	1.0
hull	2.7	1.1	30.3	32	0.5
groat	15.9	5.9	1.9	92	1.9
Barley grain	11.9	2.4	4.5	79	1.5
hull	5.9	1.3	26.4	41	0.6
groat	11.6	2.0	2.4	80	1.9

fied by seasonal growing conditions. Not only do the seeds themselves vary but the crops as harvested may include, in addition to the grain intentionally planted, the seeds from an assortment of other plants of volunteer origin from a previous crop or from weed impurities in the planting grain. Corn (maize) and wheat are relatively free from or are easily freed of such contaminants, but with barley and oats purity of sample is often a factor influencing feeding value.

Barley. Many of the problems of nutritional quality in basal feeds are particularly well illustrated in the case of barley as it is grown, sold, and used in Canada. This grain may be grown for malting purposes or for feeding livestock.

The scheme (Canadian) devised as a basis for the payment to the producer for barley delivered to elevators involves a grading according to the purity of the crop, its variety, and its soundness. Samples, which because of admixtures of seeds from grains other than barley, or because of frost or heating damage or poor filling of kernels, are not suitable for malting, are classed as feed barley.

Feed grades of barley **(*Canadian*)**. There are three grades for feed barley. These are partially defined in Table 11-7. As we can see from this table, No. 1 Feed barley is essentially pure barley, but because of frosting or for some other reason it is below the standard weight of 48 lbs. per measured bushel for malting barley.

TABLE 11-7 *Partial Description of Feed Grades of Western Canadian Barley*

Grade name	Minimum weight per bushel	Maximum tolerance of foreign material: Weed seeds (too large to pass 4/64 screen)	Wild oats	Other grains	Total non barley not to exceed
	lbs	%	%	%	%
No 1 Feed	46	1	4	4	4
No 2 Feed	43	2	10	10	10
No 3 Feed	—	3	20	20	20

Also, in this category is found barley that, because of variety, is not suitable for malting (Some varieties of barley peel too easily and, consequently, are not wanted in malting grades)

Barley that is still lighter in weight per bushel and that may also contain up to 10% of non-barley is classed as No 2 Feed The No 3 Feed grade has no minimum weight per bushel and, furthermore, need only be 80% in purity

We should note that the non-barley material may be wild oats, or it may be "other grain," which, in practice, is the same as saying it may be domestic oats and/or wheat

All Canadian barley that goes through commercial channels to the feed industry, or to Canadian purchasers of Feed barley, or is sold for export, is by law sold under one or other of these three categories (except that Eastern Canadian barley, though graded similarly, differs slightly in grade specifications)

Of course samples of grain as harvested seldom, if ever, contain exactly these quantities of foreign materials The botanical make-up of the foreign material in barley as harvested (presuming pure barley was seeded) will depend largely on what crop was grown on the area the year immediately preceding and on the extent of the weed polution An extensive survey of the 1949 Western Canada barley crop deliveries to county elevators yielded the figures in Chart 11-A as to purity and chief grain diluents

Chart 11-A indicates that a little more than half (52%) of the individual crops as harvested were essentially pure barley Roughly a quarter of the crops were about 90%, and the balance of the crops considered on the whole would be similar in feeding characteristics to mixtures carrying 80% barley Similar surveys in subsequent years revealed the same distribution of the "barleys as harvested "

CHART 11-A *Batanical Make-up of "Barley" as Harvested (Figures are per cent of samples in "diluent" categories indicated)*

Diluent		% Wheat in Crops 0	5	10	15	20	25
% Oats in Crops	0	52	11	2	.5	.5	.5
	5	12	4	2		.5	
	10	8	2	1			
	15	1	1	.5			
	20	.5					
	25	5					

Nevertheless, all commercial samples of Canadian feed barley carry approximately the maximum tolerance of non-barley This is accomplished by "blending" at terminal elevators This hospitalization may include "blending" of wild oats and coarse grains removed from wheat

To describe the feeding value of "barley" as this crop actually appears in commercial channels in Canada is, consequently, not a simple matter To be realistic we must consider under the name 'barley" at least four products

A Pure barley (including No 1 Feed Grade)

B Barley containing 9% of an unspecified combination of oats, wild oats, wheat or flax plus 1% of coarse weed seeds (No 2 Feed Grade)

C Barley carrying 17% of an unspecified combination of oats,

similar bulkiness made up of light barley plus wheat A graph showing the quantitative relations just described, prepared from a series of feeding tests with market pigs conducted at Macdonald College over a period of several years illustrates these findings (see Fig 11-4)

We should expect the same type of effect described for pigs with

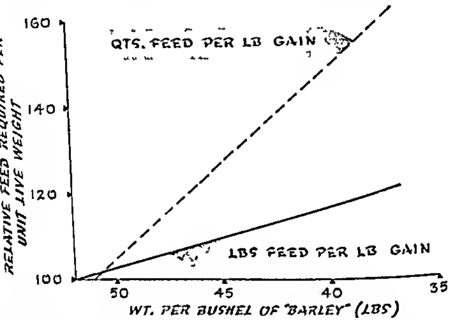

Fig 11-4 *Showing relative increases in quantities of ration required to produce on unit live weight gain on full fed bacon pigs during the last 2 months of feeding*

cattle or with sheep, but to a lesser degree due to the greater ability of ruminants to utilize crude fiber

We should note however, that in practical feeding it has seldom been possible to detect any effect of additions to pure barley of up to 10% of other grains On the other hand barley samples carrying 15% or more of either oats or wheat are likely to show measurable differences in feeding value The effect of wild oats is merely an exaggeration of that produced by tame oats

As measured by the nutritional needs of animals, all barleys are deficient in salt, calcium, phosphorus, iron iodine, and cobalt of the minerals, and in Vitamins A and D Except for herbivorous ani

mals, barley also requires supplementation with protein to increase its quantity for those samples of less than about 12% protein, and in all cases to improve its quality by enhancing particularly the lysine content.

Many statements to the contrary notwithstanding, there is no acceptable evidence that once animals are accustomed to it, pure barley is less acceptable than any other entire cereal grain. Contamination with weed seeds will adversely affect its palatability, and use of such samples may explain the lower opinion some feeders have of barley than is justified by results with clean samples. Barley is frequently planted on wheat land that has become fouled with weeds, and among wheat raisers it is referred to as a cleaning crop. Thus, more often than other grains, barley as harvested may be badly contaminated with weed seeds. Barley meal made from such low grade grain may be unpalatable, but this effect should not be charged to a characteristic of the barley itself.

Nutritionally the limit of its inclusion in specific livestock rations is set only by the quantities of other products that must be included in order to make good the nutritional deficiencies of the barley, except that for very young animals it may be desirable in some way to reduce the quantity of hull of the ration either by coarse grinding and sifting or by dilution with low-fiber feeds.

In practice, there are at least two uses to which "barley" is often put where the kind of "other grain" diluent may be of significance. When market pigs intended for lean bacon are finished on barley diluted with wheat there is a tendency for the production of overfat carcasses. On the other hand, dilution of barley with oats tends to reduce the available energy concentration and, consequently, tends to produce less fattening. Similarly, non-producing stock being carried on maintenance rations can advantageously use the barleys of lower weight per bushel such as oat and wild oat–light barley combinations.

Finally, it may be in order to call attention to the "black sheep" of the barley family—a product officially designated as *barley feed*. It consists of the mill-run residue from the production of pot and pearl barleys. The residue is barley hull plus the outer layers of the kernel resulting from the polishing of the dehulled grain to get

rid of the bran and embryo portions. This product is of low feed value, having at best only two-thirds the digestible nutrients of typical barley. We mention it here because it sometimes is illegally incorporated into ground barley or into barley containing meal mixtures. Its presence will lower the efficiency of the feed containing it, both by reducing the acceptability of the ration to the stock and by reducing available energy.

Oats. What has been said concerning the variability of barley as harvested applies, in general, to oats as a basal feed, the chief difference being that whereas barley normally carries about 6% crude fiber, oats carries 10 or 11%. Oats, in other words, starts at a lower level of energy value than barley. Variation between samples is fully as great as that with barley, and the consequences of the differences in weight per bushel follow the same pattern as those

CHART 11-B *Botanical Make-up of "Oats" as Harvested (Figures are per cent of samples in "diluent" categories indicated)*

Per cent Diluents		Wheat 0, Barley 0	Wheat 0, Barley 5	Wheat 5, Barley 0	Wheat 5, Barley 5
Wild oats 0	Chaff 0	45	5	7	2
	Chaff 5	9	2	2	
Wild oats 5	Chaff 0	11	1	3	
	Chaff 5	3			
Wild oats 10	Chaff 0	2			
	Chaff 5				

described for barley The botanical make-up of "as harvested" Canadian oats is shown in Chart 11-B

There is no experimental evidence to support the contention put forward by some feeders that oats has any special nutritional virtue for any particular class of stock It is true that the hull of the oat is somewhat softer and perhaps less irritating in the digestive tract than is the hull of barley

Barley groats, oat groats, wheat, polished rice, and corn all are rich sources of available energy and have about equivalent feeding value in the ration The chief differences in these grains as feeds are traceable to the proportions of the hull, or more specifically to the level of crude fiber

Buckwheat

Perhaps the only other individual grain feed of the basal group that requires special mention is buckwheat, and at the outset we should call attention to the problem of names of buckwheat products

The offal of buckwheat milling consists primarily of black hulls and of middlings, the latter made up of the seed coat, the adhering endosperm, and the embryo The hulls, which represent almost 30% of the weight of the entire buckwheat, have little feeding value The middlings are rich in protein and fat, which are derived chiefly from the aleurone layers and the embryo tissues So-called buckwheat feed is a mixture of hulls and middlings The proximate composition of these three products as given by Winton is in Table 11-8

TABLE 11-8 *Proximate Composition of Buckwheat By-Products*

	Water	Protein	Fat	Fiber	N free extract	Ash
	%	%	%	%	%	%
Entire seed	12 6	10 0	2 2	8.7	64.4	2 1
Hulls	6 5	7 8	1 4	33 6	47 1	3 6
Middl ngs	10 0	26 7	7 2	6 8	44 6	4.7
Feed	10 0	15 9	4 1	22 0	44 8	3 2

We can see that entire buckwheat is a basal feed, buckwheat feed a roughage, and the middlings a protein supplement

The one particular feature that we should mention here is that products containing the hulls are likely to carry enough of a photoporphyrine to cause light sensitization in white skinned animals When exposed to the sun a rash may develop of such severity as to adversely affect the performance of the animals

Entire buckwheat is frequently incorporated into poultry scratch grain mixtures but is less often used for other classes of stock Buckwheat middlings, however, is a common feedstuff in districts where buckwheat growing is a regular practice The hulls, because of their woody nature, are particularly indigestible and practically useless for feeding purposes

Wheat Bran and Other Wheat Milling By-Products

Wheat bran has had a rather checkered career as a feedstuff Originally discarded as a worthless offal from the milling of wheat for flour, it was suggested and eventually popularized as a livestock feed by Dr Henry of Henry and Morrison fame

In some districts farmers began to consider this feed indispensable and shortages developed so that bran was rationed by some feed dealers, allocating it only where other feedstuffs were also purchased The wheels of fortune turned on occasion, however, and bran became a drug on the market To ease their selling problems some millers made the sale of wheat flour to jobbers and bakers contingent on the purchase of bran in amounts equal to that represented by the milled flour This practice led to the situation where the feeder bought his supplies of bran from the baker The feeder soon realized that he was getting to be a pawn in the game of the disposal by the flour miller of one of his by-products—made possible by the feeder's belief that bran was a necessary ingredient of a satisfactory livestock ration This belief is gradually being dispelled, and bran is more and more used as it should be, specifically to capitalize on its unique nutritional properties Its light, bulky physical nature, together with its 16% of protein of high quality (a chemical score equal to that of beef

muscle) and high phosphorus content give bran a unique place in livestock feeding About 40% of the germ of the wheat is in the bran, which accounts for its high quality of protein Included in the herbivor ration, it provides supplementary phosphorus to correct the common shortage in the forage and its cellulose-hemicellulose carbohydrate is, of course, an acceptable source of energy for these animals Its bulk is often advantageous as a means of lightening the heavy concentrated nature of a predominantly corn ration

The bulky nature of bran is of special usefulness in the preparation of non-fattening rations, as for the bacon hog With this class of animal bran yields less energy than to cattle, and thus its introduction into the meal mixture of market pigs during the last two monhs of feeding before slaughter has the effect of curtailing the energy intake and thus the fattening of the pig, without feed restriction Canadian experiments and practical experience has demonstrated that hog finishing rations diluted with 25% of wheat bran by weight can be self-fed to market pigs without the penalty of the excessively fat carcasses which otherwise result from self-feeding practices

None of the other wheat milling by-products shorts, middlings, feed, flour have any of the special properties of the wheat bran They are basal feeds useful largely in proportion to their TDN and other nutrient values

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CHAPTER 12

Protein Supplements

Products of Plant Origin

AS WE INDICATED in the feed classification, the protein supplements of plant origin divide quite naturally into two subgroups—the one containing the feeds that carry from 20-30% total crude protein, and the other those running from 30-45% crude protein

In order to picture certain of the characteristics of these two groups of feeds, we have entered a few of the more common products belonging to each in Table 12-1

Insofar as we can describe them by averages, we can see that the chief difference between these two types of supplements is in protein content, the higher protein being associated with a lower carbohydrate analysis The 20-30% group is made up primarily of by-products of wet milling, brewing, or distilling of corn or barley The by-products tend to be high in crude fiber The feeds of the other group are almost entirely residues of oil-bearing seeds, which have been processed by chemical extraction or by expression to remove most of the oil The carbohydrate is relatively low Because of a higher fat content, the TDN is likely to be somewhat higher in this group of feeds than in the 20-30% group

In the matter of quality of protein, it is evident from the chemical scores that the feeds in the 20-30% group are poorer than are those of the higher protein category Perhaps the reason for this difference is that less of the germ proteins are removed in the process of fat

TABLF 12-1 *Typical Protein Supplements of Plant Origin (all figures are %)*

	Feedstuff	Crude Protein			Crude fat	Carbohydrate		Usually used value for TDN		Calcium	Phosphorus
		Total	Digestible (cattle)	Chemical Score		Crude fiber	N free extract	Cattle	Swine		
	Gluten feed	25	21	21	3	7	46	75		14	.55
20%	Distillers grains	27	19	21	10	12	33	81		.11	47
to	Brewers grains	22	18		7	16	40	60	43	25	49
30%	Malt sprouts	23	17		2	16	40	65			
	Average	24	19	21	5	13	40	70		17	50
	Oilmeals* of:										
	Linseed	36	29	43	6	8	34	76	68	44	94
30%	Cottonseed	41	34	50	5	6	25	79	73	23	1 14
to	Soybean	44	36	56	6	6	29	77	74	26	.59
45%	Peanut	44	40	41	7	5	24	80	82	.16	.54
	Sunflower	39	34		14	12	20	72			
	Rapeseed	31	27		12	9	30	73			
	Average	39	34	48	8*	8	27	76	74	27	80

* Solvent extracted materials will average 1.5% fat, with protein and carbohydrate proportionally increased

extraction than they are with the water treatments involved in wet milling or brewing. The feeds of this lower protein group are by-products either of corn or barley, and the chief, or at least the first limiting factor in their quality is a deficiency of lysine. Malt sprouts, however, presents an exception to this rule, where the protein is a combination of the proteins found in the barley grain together with those of the newly sprouted root. At the moment there is no experimental evidence that gives qualitative differences between these two proteins, but there is every reason to believe that the proteins of the rootlet will be similar to those of leaf. We believe also that young leaf proteins may be of a more complete amino acid make-up than we find in the seed of the plant.

Oilmeals. In spite of the overall better quality, the first limiting amino acid of linseed and cottonseed is lysine, but with the peanut meal the sulfur-containing amino acids, methione and cystine, are relatively the more deficient, with lysine standing second. Soybean oilmeal proteins, on the other hand, are probably the most complete of any of the plant seed proteins. Table 12-2 gives an idea of the amino acid distribution in the protein of the important oilmeals, which may be of interest at this point.

It is evident, therefore, that supplementation of the basal feeds with any but soybean oilmeal of the high protein feeds of plant origin is not likely to result in improved biological values. Most of these feeds have a common deficiency in lysine, which sets an upper limit to their usefulness in rations of animals where quality of protein must be considered.

Crude Fiber. The feeds belonging to the lower protein category among the supplements are likely to have a higher crude fiber content than are those of the oilmeal group. It is perhaps for this reason that such products as brewers' grains, malt sprouts, and distillers' grains are not as commonly thought of as hog feeds. The higher fiber content is of less direct consequence in the dairy ration.

The important factor here is the effect of the bulkiness of the feed. Bulk becomes important in practical feeding of cattle because

TABLE 12-2 *Partial Amino Acid Content of Oilmeals as a per Cent of Their Dry Matter (Dried skimmilk and corn for comparison)*

Amino acid	Dried skimmilk 34%	Linseed oilmeal 33%	Soybean oilmeal 45%	Cottonseed oilmeal 42%	Corn gluten meal 42%	Peanut oilmeal 45%	Whole corn 9%
	%	%	%	%	%	%	%
Arginine	1.46	2.04	2.61	3.11	1.30	4.46	0.36
Histidine	0.85	0.49	1.03	1.09	0.71	0.95	0.22
Lysine	2.55	0.82	2.43	1.13	0.46	1.35	0.23
Tyrosine	1.80	1.68	1.85	1.34	2.60	1.98	0.55
Tryptophane	0.54	0.63	0.63	0.55	0.25	0.45	0.05
Phenylalanine	1.93	1.85	1.85	2.77	2.77	2.43	0.41
Cystine	0.37	0.63	0.59	0.84	0.50	0.72	0.10
Methionine	1.12	0.99	0.81	0.67	2.31	0.41	—
Threonine	1.56	1.68	1.80	1.26	1.68	0.68	0.32
Leucine	5.10	—	3.60	5.88	10.50	4.50	1.94
Isoleucine	1.53	1.15	1.80	1.47	2.10	1.58	0.32
Valine	2.20	1.98	1.58	2.94	2.10	3.15	0.41
Glycine	0.13	—	0.45	2.22	1.80	2.52	—

allowances are measured by volume rather than by weight. As a ration is made bulkier by the inclusion of light feeds, the volume quantity of a ration required to yield the amount of digestible energy called for by the feeding standard increases rather rapidly.

For example, we can assume for rough calculation that a meal mixture of standard feeds carrying 75% TDN will weigh about one pound per quart, and that one of the 70% TDN will weigh only about .8 lb. To supply one pound of TDN we require 1.33 lbs. of the heavier and 1.43 lbs. of the lighter feed. But if we express the allowance is in quarts, we find that for 1.33 quarts of the heavier mixture we shall require 1.80 quarts of the lighter one. The increase in the case of weight is about 7%, but by volume it is 35%.

Insofar as the cattle themselves are concerned, added bulkiness of ration is of little importance. The difficulty lies with the feeder

who is not always fully aware of how many more quarts of bulky ration must be fed to supply the nutrients contained in a more concentrated feed mixture

Calcium and Phosphorus. The calcium and phosphorus content of these protein supplements should be compared to the probable concentration required in the complete cattle ration Feeding standards indicate that approximately .2% of the dry weight of the ration should consist of calcium plus about an equal quantity of phosphorus Daily allowances of good quality roughage can be expected to supply all of the calcium that cattle require The importance of the concentration of this element in the feeds of the meal mixtures is, therefore, small In any case, these feeds will usually constitute no more than 15-20% of the final meal mixture fed and their calcium content, therefore, will not be important in changing the calcium content of the ration

The problem of phosphorus, however, is somewhat different This element in feeds is quite likely to be correlated in amount with protein content Thus, high protein feeds commonly provide more phosphorus than low protein feeds In general, the feeds of the 20-30% protein group supply about double the concentration of phosphorus that is required in the final ration of cattle stock, and the feeds of the 30-45% category supply somewhat more Thus, as the protein level of the meal mixture is increased by the addition of protein supplements, the phosphorus is also augmented As we shall explain in more detail under formulation of rations, this correlation does not necessarily mean that a phosphorus supplement can be omitted from the meal mixtures of milking cows

Effects of Processing. We have already suggested that the by-product feeds are likely to be more constant in chemical make-up than are the unprocessed basal feeds There are nevertheless differences in the processes to which by-product feeds may have been subjected, some of which have a bearing on their effective nutritional values The use of heat, for example, may be either detrimental or beneficial, depending on the feed and depending on the amount of

heat Soaking of the product and subsequent drying may also have an effect on the availability of some of the nutrients of the resulting products

With feeds that are by-products of brewing or distilling, the heat involved is usually that necessary for the drying of the product The cost of this operation is appreciable, and in some cases suppliers offer samples that have not been dried sufficiently to ensure that the feed can be safely stored Storage in the usual warehouse of feeds that contain appreciably more than 12% of moisture invites risk of spoilage It may be worth commenting here that high moisture samples should be priced so that the unit cost of dry matter is equivalent to that asked for normally dry samples

With the oil bearing seeds, the use of heat is for a somewhat different purpose It may be applied intentionally, or it may be incidental to the process of fat extraction In general, there are three oil milling methods The "old process" is more properly termed the 'hydraulic process,' in which the seed is crushed into flakes and these are then subjected to steam cooking The hot wet mass is spread in layers between heavy cloth and placed in a hydraulic press where as much of the oil as possible is squeezed out by pressure The resulting cakes may then be broken into a granular form and sold as oilcake, or they may be ground into a fine meal In this process the residue still retains 5% or more of fat

The expeller process is not unlike the hydraulic process in principle The seed, after cracking and drying, is heated in a steam jacketed apparatus, and subsequently the mass is subjected to pressure in a screw press A considerable amount of heat is generated from friction in this process The residue is again ground into a meal About the same proportion of fat is extracted by this process as in the hydraulic process

The solvent process is quite different, it employs a volatile fat solvent, in which the flakes are soaked or washed Once the oil has been thus removed the residue is heated to remove the last traces of the solvent Usually only about 1% of fat remains in the oilmeals prepared by this process Oilmeal prepared by solvent extraction

may require further heating or "toasting" to improve digestibility. Whether or not this extra treatment is necessary depends on the particular protein involved.

Soybean protein is enhanced in feeding value for non-herbivorous animals by sufficient heat treatment to destroy a substance present in the soybean that otherwise inhibits proteolysis. There may also be some change in the protein molecule itself, which increases the availability of the cystine and methionine. Experiments indicate that methionine in heated soybeans is more rapidly liberated by enzymic action than with an unheated product. Soybean protein is not the only one that is improved in digestibility by cooking. The proteins of the navy bean and of the velvet bean are in this category.

We should note, however, that in these cases where heat does improve protein value, the temperature, time, and heat intensity are of importance. Too severe treatment will undo the favorable effects of a milder treatment.

The proteins of most feeds, on the other hand, show a decrease in nutritive value when subjected to heat. Experimental evidence seems to indicate that when heating damages a protein, the damage is likely due to a destruction of lysine. At least a number of heated proteins are restored to their original value by additions of lysine. Lysine, in fact, is rather easily damaged, and some evidence indicates that even mild drying of some proteins of animal origin may be detrimental.

To come back to the oil meals, we know that cottonseed meal and peanut oilmeal may be damaged by heat treatment, both in digestibility and in biological value.

Mitchell and Block* come to the conclusion that food products whose unheated proteins are ranked lower by a biological assay than by a chemical appraisal by chemical score will probably show an improvement in biological value on heating; while those food proteins whose biological assays and chemical ratings show reasonable agreement are likely to be damaged in biological value by heating.

Insofar as the proteins that are ordinarily fed to livestock are con-

* *Nut. Abst. and Rev.*, V. 16, No. 2 (1946).

cerned, only the proteins of soybean products appear to be improved by heating The others are more likely to be damaged primarily through destruction of lysine

Fat level. The matter of the fat content of oil-bearing seed by-products is one which must be taken into account sometimes if they are to be used for certain classes of livestock Most vegetable oils, if fed to meat animals in any appreciable amounts for periods of a month or more previous to the slaughter of the animals, tend to produce a soft oily fat This is particularly objectionable in the case of pigs For hogs whose carcasses are to be made into bacon, heavy feeding of corn (of only 5% fat) during the finishing period may be sufficient to cause this softening of the fat Thus the feeding of the oil seeds as grown on the farm is not ordinarily a desirable procedure Extraction of the oil leaves a residue that in different instances may contain from almost none to 10-12% of fat, depending on the process and the efficiency with which it is operating It is possible to feed ground soybeans, ground peanuts or other feeds of this type to cattle without undue penalty in carcass quality, but these products cannot safely be fed to finishing pigs However, they are sometimes used for younger pigs

Expeller oilmeals will carry about the fat content shown in Table 12-1 The use of solvent extraction is increasingly common, with the result that the fat content of the oilmeals so treated is reduced to about 1% This reduction of fat means an increase in protein and in carbohydrate concentration but a *reduction of about 5 percentage units of TDN in energy value* The alteration of protein level is great enough to be nutritionally and economically important, but the changes in the other nutrients are not likely to have measurable effects in the final ration

We should also call attention to the high TDN values for most of the products of this category With the exception of brewers' grains and malt sprouts, the inclusion of almost any one of the protein supplements of plant origin in the typical rations of livestock enhances the TDN as well as the protein Thus, where they are of

competitive price per unit of TDN these feeds can be included for their energy value equally as well as the basal feeds. There is no acceptable evidence that excesses of protein, such as might be caused by supplementation of this kind, are likely to be of practical significance.

Precautions. Most of the oilmeals are wholesome and palatable to all classes of livestock. An exception would be *unheated soybean oilmeal* as an ingredient in the hog ration. The toasted product, however, is entirely satisfactory. There are, nevertheless, some precautions to be used in connection with some of these oilmeals. *Cottonseed meal,* for example, must be used cautiously with any but adult cattle stock because of the poisonous nature of the gossypol, which may be present in grades of meal containing appreciable amounts of the cottonseed hulls. Thus, low grades of cottonseed meal should be especially avoided with young animals whose susceptibility is greater to this poisoning than it is with older stock, and even the high quality products should be avoided for pig feeding.

Rapeseed oilmeal is another product of this protein supplement category that has peculiarities due to glucosides from which mustard oils may be formed in the digestive tract of animals under certain conditions. These oils are irritating and produce undesirable consequences when they are included in too large quantities in livestock rations. In actual practice the inclusion of much over 4 or 5% of rapeseed oilmeal in livestock rations renders them unpalatable. Here, again, young animals and possibly pregnant females may be more susceptible than other classes to the harmful effects of rapeseed oilmeal.

The special property that has been claimed for *linseed oilmeal* may be questioned. Raw linseed oil is sometimes used as a laxative with farm animals, and many statements have appeared to the effect that one of the beneficial effects of linseed oilmeal can be traced to the 8 or 9% of oil in the product. This was supposed to help lubricate the digestive system and to correct the constipating effects of dry hay or other feeds of that nature. There was also the belief

that cottonseed meal tended to be constipating Experimental evidence does not support the presumed difference between linseed oilmeal and cottonseed meal in this respect In fact, tests indicate that the rate of passage of diet "residues" through the digestive system of various kinds of animals is not differentially affected by the normal use of either of these feeds

Soybean Oilmeal. The special role of soybean oilmeal as a protein supplement requires comment At least in North America soybean oilmeal has become the key feed among the protein supplements of plant origin The extent of its use in different parts of the U S and Canada at any one time is influenced by its price in relation to that for other oilmeals Because of its higher biological value this feed has now replaced much of the meat meal, tankage, and fish meal, which were in the past the mainstay of protein quality in rations for non herbivorous animals

Insofar as the biological value of the protein in soybean oilmeal is concerned, it is interesting to compare its amino acid makeup with that of the protein of milk and of linseed oilmeal, the former is a protein of nearly perfect biological value, and the latter is a plant protein that is still the standard in many districts of North America This comparison is given in Table 12-3

TABLE 12-3 *Partial Amino Acid Makeup of Soybean and of Linseed Oilmeal Dry Matter Relative to That of Milk as 100*

Amino Acid	Soybean Oilmeal	Linseed Oilmeal
Lysine	95 (76)*	32
Tryptophane	120 (96)	120
Cystine	160 (128)	170
Methionine	72 (57)	88
Isoleucine	117 (94)	75

* Corrected to 34% crude protein

This way of comparing soybean protein quality leads to the conclusion that the chief advantage it has over linseed meal protein is

its markedly greater concentration of lysine, the amino acid that is ordinarily the first protein quality deficiency of the basal feeds.

However, the particular amino acid distribution of this feed appears to be such that in combination with corn (and necessary mineral and vitamin supplements) it forms a ration in which little or no animal or marine protein is necessary for hog feeding. Thus where high grade fishmeals or meatmeals are not readily available and/or are not competitive in price, soybean oilmeal offers a valuable alternate source of protein.

Protein Supplements of Animal and Marine Origin

Analogous to the high protein feeds of plant origin is a group of edible by-products of animal or fish origin. These are usually employed to enhance the total protein of basal feeds, but, in addition, they contribute to the mixture a sharply different proportion of a number of amino acids from that characteristic of most proteins of plant sources. For example, plant seed proteins are usually seriously deficient in lysine. Meat, milk, and fish proteins, however, are relatively rich in this amino acid, though they are themselves likely to be short of the sulfur-containing cystine and methione.

The products belonging in this high protein group are more diverse as to protein level than are feeds of any other protein category. The individual feeds frequently have unique properties affecting or limiting their use. Some of these are indicated by chemical make-up as shown in Table 12-4.

Excluding whey powder, which really does not belong in this category but will be discussed here because of its protein characteristics, we can see that the range of protein values is from 34 to 82%; the fat ranges from essentially 0 to 15%; and the calcium and phosphorus values with some of the feeds are present in supplementary amounts. There are several grades of both tankage and fish meal, representing differences in processing, which result in products of distinctly different characteristics as feeds. However, before dealing with individual products we should note the general feeding characteristics of the feeds of this group.

TABLE 12-4 *Composition of Typical Feeds of Animal or Marine Origin*

	% Protein		% Ether extract	% Ash		% TDN
	Total	Digestible		Ca	P	
Meat meal	55	50	10	8 70	4.30	74
Meal and bone meal	46	42	12	11 0	5 20	68
Blood meal	82	65	1	33	26	61
Tankage				6 20	3 40	
low fat	68	60	3			65
high fat	61	45	15			77
55% protein	58	36	11			68
70% protein	73	70	12			94
Fish meal				5.40	3 00	
low ash (14)	71	66	6			78
high ash (31)	52	48	1			49
50% protein	53	49	4			55
70% protein	74	71	1			71
65% protein (oily)	68	65	10			87
Milk						
skimmilk powder	34	33	1	1 25	1 00	85
whey powder	12	11	1	1 18	0 66	84

Protein Quality. With regard to protein, there is a remarkable similarity in the amino acid distribution of the different feeds (see Table 12-5) All carry as much or more lysine than is found in the protein of egg (which is usually taken as the standard of excellence in regard to amino acid assortment) As compared to the average cereal grain protein, animal or marine proteins have a higher lysine level by about two and a half times (see Table 12-6)

The isoleucine level of meat meal, fish meal, and milk is at least 50% higher than that in the mixed proteins of cereals, but blood meal and, consequently, tankage, which contains blood, is low in this amino acid Because of their lysine and in most cases their isoleucine levels, the feeds of this group are valuable as supplements

TABLE 12-5 *Essential Amino Acid Content of the Proteins of Certain Animal Protein Feeds (As a per cent of total protein)*

Amino acid	Tankage	Meat meal	Blood meal	Fish meal	Milk	Egg
Arginine	5.9	7.0	3.7	7.4	4.3	6.4
Histidine	2.7	2.0	4.9	2.4	2.6	2.1
Lysine	7.2	7.0	8.8	7.8	7.5	7.2
Tyrosine	2.9	3.2	3.7	4.4	5.3	4.5
Tryptophane	0.7	0.7	1.3	1.3	1.6	1.5
Phenylalanine	5.1	4.5	7.3	4.5	5.7	6.3
Cystine	—	1.0	1.8	1.2	1.0	2.4
Methionine	—	2.0	1.5	3.5	3.4	4.1
Threonine	3.0	4.0	6.5	4.5	4.5	4.9
Leucine	7.7	8.0	12.2	7.1	11.3	9.2
Isoleucine	2.7	6.3	1.1	6.0	8.5	8.0
Valine	5.4	5.8	7.7	5.8	8.4	7.3

TABLE 12-6 *Comparison Between Proteins of Cereal and Animal Origin (Figures are per cent of total protein)*

Amino acid	Cereal*	Animal†	Egg standard
Arginine	4.8	5.7	6.4
Histidine	2.1	3.3	2.1
Lysine	3.1	7.7	7.2
Tyrosine	4.8	3.9	4.5
Tryptophane	1.2	1.1	1.5
Phenylalanine	5.7	5.4	6.3
Cystine	1.7	1.2	2.4
Methionine	2.3	2.6	4.1
Threonine	3.4	4.5	4.9
Leucine	7.1**	9.2	9.2
Isoleucine	4.3	4.9	8.0
Valine	5.2	6.6	7.3

* Wheat, corn, rye, oats

** Corn not included in this average. It carries 22% of its protein as leucine.

† Tankage, meat, blood, fish, milk

to the plant proteins, the combinations usually having a higher effective biological value than that of plant protein alone

As a group, the feeds of this category are deficient in the sulfur-containing amino acids, cystine and methionine Methionine can, of course, be converted *in vivo* to cystine (although the reverse is not true) Hence the combined deficiency of these two acids can be relieved by fortification of the diet with pure methionine, which is economically available as a feed supplement

It is now believed that the biological function of methionine as a methyl group donor can be replaced at least in part by Vitamin B_{12} in its role of facilitating syntheses involving these CH_3 groups In practice therefore any reduced biological value of the proteins of meat, fish, and egg (or, of course, of any other feed) caused by shortage of cystine and methionine can be so easily and effectively corrected that it can be largely disregarded (assuming, of course, the correction is made) The feeder has the option of adding methionine, or Vitamin B_{12}, or both

Ash. Another characteristic of this group of feeds is their high ash and especially their high calcium and phosphorus Whereas the plant products carry less than 1% of either of these elements, and more often only ¼%, meat and fish meals run from 5 to 11% calcium and from 3 to 5% phosphorus These high levels are, of course, due to the presence of appreciable amounts of bone In general the higher the protein in either meat or fish meals, the lower the calcium and phosphorus In many meal mixtures the desired supplementation of the basal feeds with these two minerals is accomplished incidental to the use of meat or fish meals in amounts needed to adjust the protein quality or quantity

Fat. Both tankages and fish meals may have widely different fat percentages Fat in either of these products is nutritionally a liability It is unstable and hence complicates the feed storage problem The onset of rancidity not only may adversely affect palatability but may result in residues that catalyze the destruction of oxidizable nutrients in the ration, especially Vitamins A and E Also, with the feeding

of oily fish meal there is the possibility of taints in milk, egg, and flesh; as well as the production of oily (or soft) pork. Hog carcasses graded "soft" are unsuitable for bacon.

Individually some of the feeds of this grouping have peculiarities which we should note especially.

Skimmilk, for example, stands out by itself in this group of feeds. Its protein is almost perfectly digested and its biological value is usually rated as next below that of egg (actually its egg replacement value is about 96%). Its calcium and phosphorus are relatively low as compared to the feeds carrying bone. Thus it can constitute a large fraction of the ration without introducing excessive minerals. It contains no digestion resistant components comparable to the tendons and ligaments that form a part of tankage. Nor has skimmilk any damaging fat content. Therefore, it is often used as an important source of protein in the rations of young animals. In this role its high riboflavin is also a decided advantage. Its relative, *whey powder*, however, is not a protein supplement in the usual sense. But in grain mixtures where the protein level is already adequate, its exceptionally high lysine and riboflavin content can often be used to advantage, even though its total protein is about that of basal feeds. Thus, hog rations, which because of the liberal inclusion of high protein wheat already carry 15% of total protein, may be fortified with needed lysine through the use of this relatively cheap but low protein dairy by-product.

Blood meal, for another example, is unexpectedly low in digestible protein. This unexpected peculiarity is due to the fact that hemoglobin is resistant to proteolytic enzymes, perhaps because of the effect of high heat in drying the blood. Furthermore, the effective biological value of its protein is low as compared to that of the other feeds of this category.

From Table 12-4 we can see that *tankage* may be a variable product with regard both to fat and to protein. The fat level often appears to reflect the market demands for soap fats. When these are in surplus, the tankage fat levels may rise, presumably as a secondary outlet for the fat. High fat tankages are not only less stable than low fat samples, but have a much reduced protein level. If the tank-

age is to carry only 45% digestible protein, meat meal is usually a preferable choice, since it is likely to be largely muscle trimmings, whereas tankage contains appreciable quantities of gut, tendon, and connective tissue, the proteins of which are of somewhat poorer biological value than are those of skeletal muscle

High protein tankages are usually prepared and standardized by adding necessary amounts of blood meal to a lower protein tankage base Tankage may contain up to 35% of blood, which probably does not enhance its biological value Another significant point in the discussion of tankage is that present day tankage does not contain appreciable amounts of glandular organs, since these are likely to be used as sources of extracts that eventually find their way into pharmaceuticals Loss of the glandular materials has been detrimental to the feeding value of tankage

High fat *fish meals* also present problems we should discuss at this point Some fish meals are by-products of the fish filleting business and consist of the entire fish (sometimes including entrails) minus the fillets removed The fat content of such materials will depend in large part on the kind of fish involved Thus white fleshed fish, including cod, haddock, hake, pollock, skate, and monk fish, can be processed into the relatively low fat "white fish meal"

Meals from herring or pilchard, on the other hand, are not by-products of filleting, but of the fish oil industry These meals carry considerable oil, the level depending in part on the freshness of the fish at processing In the case of pilchard, operators claim that if the fish are not processed within 3 days of being caught, it is impossible to produce, without solvent extraction, a fish meal of less than 9% fat Furthermore, poor processing also results in a high oil meal Thus fish meal carrying more than 9% of fat is not only less desirable as a feed because of its oil, but also because its high oil content is indicative of a product made from stale fish, or of one that is the result of bad processing These were the factors that led to the requirement in Canada that fish meals of 9% or over of fat be labelled as *oily* Fish meals that are residues of oil recovery by the "sun rotting" process are invariably oily, sometimes running as high as

20% ether extract. Such products should be avoided in the feeding of farm livestock.

Another matter we should comment on before leaving the subject is the various kinds of fish meal that are available. In the case of meat meal and tankage no indication is given in the name as to the kind of animal from which the material was derived. With fish meal, however, the labelling may indicate the kind of fish involved. Thus there are herring meals, sardine meals, pilchard meals, etc., as well as whale meal. Present indications are that these products are valuable largely in accordance with their protein content and that their limitations as feeds are usually related to their oil content. This is, of course, indicated on the guarantee.

One final word on fish meals concerns *salt*. Since there is an upper limit to the desirable salt (NaCl) content of animal, and especially of poultry rations, the salt content of fish meals is sometimes a factor limiting their usefulness. The Canadian law requires that the percentage be specified on the tag if the meal carries more than 4% by weight of salt.

SUGGESTED READING

Block, R. J., and Mitchell, H. H., "The Correlation of the Amino Acid Composition of Proteins with Their Nutritive Value," *Nut. Abst. and Revs.*, V. 16, p. 249 (1947).

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CHAPTER 13

Vitamin and Mineral Supplements and Miscellaneous Additives

WE HAVE DISCUSSED the basal feeds and the protein supplements largely by types as to major nutritional characteristics However, in the preparation of modern livestock rations, it is often expedient to employ one or more products as sources of certain nutrients or because of certain desirable characteristics they may impart to the ration, products that may not be feeds in the usual sense of this term These include vitamin and mineral supplements as well as products such as flavors, binders, drugs, antibiotics, animal fats, etc Generally speaking they have unique uses and hence must be dealt with individually

Vitamins

Units of Potency. The presence in edible materials of a number of nutrient substances needed for the survival and continued health of animals was discovered long before their chemical nature was learned They were given the general name *Vitamins* and the different vitamins were identified by letters, as Vitamin A, C, etc The potency of a foodstuff with respect to any one of the first few vitamins discovered was originally expressed in terms of *Units* In order that different research workers could correlate their findings, International Reference Standards for a number of vitamins were agreed on against

which to measure vitamin potency of foods and with which to express the daily need of animals

Today the needs of animals and the potency of foodstuffs as to a vitamin are usually expressed in terms of weight (milligrams or micrograms), though the use of *units of potency* is still common in referring to Vitamins A and D, and also occasionally in referring to B_1 and B_2 We have thought it desirable, therefore, to define at the outset the International Standards and International Units of Potency (i u) for these four vitamins

Vitamin A The international standard for Vitamin A is pure crystalline Vitamin A acetate The international unit (i u) is 0 344 micrograms (µg) of pure Vitamin A acetate, which is equivalent to 0 3 µg of Vitamin A alcohol The Canada Reference Standard contains 10,000 i u of Vitamin A in each gram It is distributed in capsules, each capsule containing 2,500 i u of Vitamin A The U S Pharmacopoeia (U S P) Reference Standard is the same as the Canadian Reference Standard, and the U S P unit is the same as the International Unit

Provitamin A or Carotene The international standard for carotene is a sample of pure beta carotene The international unit for provitamin A is the Vitamin A potency of 0 6 µg of the international standard (This is equivalent to 1 0 µg of mixed carotene found by analysis) Hence 0 6 µg pure beta carotene, or 1 µg mixed carotene is equivalent in Vitamin A activity to one i u of Vitamin A

Vitamin B_1 The international standard of Vitamin B_1 is pure synthetic thiamin hydrochloride The i u is the potency of 3 µg (·000003 grams) of thiamin hydrochloride

Vitamin B This is pure riboflavin and requirements are usually expressed as micrograms per day If expressed in Bourquin-Sherman units figure 400 000 units = 1 gram riboflavin

Vitamin D The international standard for Vitamin D is pure crystalline irradiated 7-dehydrocholesterol (Vitamin D_3) One i u is 0 025 µg of the international standard The U S P Reference Standard is a solution of the international standard containing 400 i u in each gram of solution

CHART 13-A *Names, Functions, Deficiency Symptoms, and Sources of Vitamins, Which Frequently are [illegible] Added to Rations*

Vitamin	Function, units of potency, etc.	Deficiency symptoms	Good natural sources	Other sources (synthetic concentrates)	Supplementary* amounts normally added per meal mixture
Vitamin A animal form; Carotene plant form	Stimulates the formation and development of body cells, hence a growth vitamin. Also involved in dim light vision. 1 microgram mixed carotene = 1 U.S.P. unit of Vitamin A.	Retarded growth of young. Interference with reproduction. Impaired night vision.	Leafy forage, fresh or preserved against oxidation loss. Milk or fish fat (variable). Yellow corn.	Pure crystalline Vitamin A acetate 3,000,000 U.S.P. units/gm. Mixed carotene carries 1,000,000 U.S.P. units/gm.	1,000,000 I.u.
Vitamin D; D_2 plant form; D_3 animal form	Facilitates absorption of calcium, hence is related to normal bone formation. Irradiation by direct sun (ultraviolet rays) effectively supplies animals with needed Vit. D. Poultry do not utilize D_2.	Rickets in young, osteomalacia in adults. Swollen and sore joints. Poor reproduction.	Sun-cured, leafy hay for animals (but not poultry)	Fortified fish oils, irradiated sterols for both poultry and animals. Crystalline D_2 or D_3 carry 40,000,000 I.u./gm.	200,000 I.u.

Riboflavin	Part of an enzyme necessary for the oxidation process in all living cells It is synthesized by micro organisms in herbivora.	Slow growth, nerve *degeneration*, diarrheo (pigs, calves), curled toe paralysis, low egg production (poultry)	Liquid, condensed, or dry milks Dried leafy forage Distillery solubles Dried Brewers' yeast.	Pure synthetic riboflavin carries 400,00D B S units/gm 1 gm has potency of 100 lbs. skimmilk powder.	300 mgs
Pantathenic Acid	A part of Co enzyme A and is necessary for the utilization of all energy yielding nutrients. Particularly important in Canada since typical Canadian hog rations are often too low in this vitamin	None in herbivora Stilted gait in pigs, especially with hind legs (often called goose stepping and confused by some with rheumatism or rickets). Dermatitis around bill and eyes in poultry	Brewers' yeast, dry milk or whey, cane molasses, alfalfa.	Synthetic calcium pantothenate (92% pantothenic acid)	2 gms
Vitamin B_{12}	A cobalt containing substance active in treating pernicious anemia Probably active part of the animal protein factor '	Poor growth, poor feathering and poor hatchability Its use usually increases gains of young by 10 2D%	Feeds of animal or marine origin Liver meal is especially potent.	Fermentation products and by products from making antibiotics	5-10 mgs for all young Adult herbivora synthesizes it.

* Roughly equivalent to about ¼ total needs of the young animals (except for B_{12}).

Characteristics of Vitamins. Insofar as the vitamins as a group are concerned, some useful information has been assembled in Chart 13-A

Alfalfa and Grass Meals. Because of the variability of leafy forages in Vitamin A potency, and the frequent use made of such feeds as Vitamin A sources, we have thought it desirable to comment further on Alfalfa and Grass Meals

Sun-cured and dehydrated greenstuffs, such as alfalfa and cereal grasses, are widely used in commercial balanced rations as sources of Vitamin A Average analyses indicate that dehydrated products range in Vitamin A potency from 168,750 i u per pound to 75,000 i u per pound, whereas sun-cured meals are highly variable but usually inferior In terms of replacement, 8 pounds of freshly processed dehydrated alfalfa meal, e g, containing 75,000 i u of Vitamin A per pound, will provide the Vitamin A equivalent of one pound of 1386A feeding oil Since carotene in these meals deteriorates with age, particularly in hot weather, it is important from a practical standpoint to calculate the Vitamin A unitage upon the content by analyses at the time of mixing This calculation will safeguard the Vitamin A level of the ration where the fullest economy of the Vitamin A activity of dried greenstuffs is sought

Vitamin B_{12}. This is one of the more recently discovered vitamins and because of its peculiarities we have considered it in more detail than could be included in Chart 13-A

After several years of research by many laboratories, the vitamin-like substance known to be present in a number of feeds of animal and marine origin, and that was responsible for spectacular increases in the growth of young animals when these feeds were in the diet, has been identified as Vitamin B_{12}. It is peculiar in that it appears to be solely a product of bacterial synthesis It is absent from plant materials Its presence in animal tissues is a consequence of storage by the animal before slaughter Its presence in such feeds as tankage or fish meal may be from bacterial activity in these products following manufacture It develops rapidly in fecal material, and the

eating of feces by pigs and poultry is undoubtedly one important method of their obtaining it. It is synthesized by rumen and caecum microorganisms and thus is available to adult cattle, sheep, and horses. The effectiveness of B_{12} supplements in rations diminishes as the ration to which they are added contains increasing amounts of such feeds as meat, fish, or milk. It is probable that in some cases the quantities of tankage and fish meal previously believed desirable can be reduced, provided some B_{12} is added from another source.

Many older recommendations, based on both practical and experimental evidence, have called for 20% of the protein for pig and poultry rations to be of animal origin. This percentage is thought to be higher than necessary to meet the amino acid demands. Using one-half the previously recommended combination of meat and fish products in a typical young pig or chick ration should supply roughly half the quantity of B_{12} believed needed in such rations, and will also result in sufficient amino acid correction to balance the plant protein.

Thus there is the probability that the supplementary addition of enough B_{12} to supply about half the total need will be a useful addition to rations intended for young animals. While the requirements of these animals are not accurately known, we have evidence that it is not far from 16 milligrams B_{12} per ton of ration, if the meat and fish are being used in the amounts indicated. Typical samples of meat meal or feeding tankage are tentatively reported to carry a potency of 0.09 mg. per pound of dry substance. Fish meals may carry double this quantity.

Minerals

With the increasing use of mineral supplements in the rations it seems advisable to indicate the more common supplementary sources of these nutrients together with notes concerning them. This information is summarized in Table 13-1.

The Fluorine Problem. The fluorine hazard in livestock feeding for practical purposes relates only to the consumption of rock phosphates and phosphatic limestones. Consequently, the starting point in

TABLE 13-1 *Summary of Sources of Minerals and Their Potency*

Nutrient	Common Source	Composition or Potency	Remarks
Calcium*	Feeding bone meal	23% Ca	Contains also 20% protein and 11% phosphorus
	Feeding bone meal (steamed)	32% Ca	Contains also 7% protein and 14% phosphorus
	Bone char	22% Ca	Contains also 11% phosphorus but no protein
	tri-Ca phosphate	38% Ca	20% P
	di-Ca phosphate	23% Ca	20% P
	mono-Ca phosphate	15% Ca	17% P
	Ground limestone	24-36% Ca	Balance is likely to be carbonate and magnesium
	Calcium carbonate	40% Ca	
	Oyster and other marine shells	38% Ca	Shells contain on the average 96% $CaCO_3$
Phosphorus	Bone meals and Ca phosphates	See above	
	Rock phosphate	14% P	Rock phosphate is 75-80% tri-calcium phosphate. Not advised unless guaranteed to contain less than 1% fluorine
	Defluorinated rock phosphate	20% P	Should not contain more than 1 part fluorine to 100 parts phosphorus.
Iodine	Potassium iodide	76% I	The potassium or sodium salt may be used interchangeably
	Sodium iodide	84% I	
	Potassium iodate	59% I	
	Iodized salt		Stabilized iodine should be used. Amounts of iodine differ but 0.02% and 0.05% are commonly sold
Iron	Ferric oxide	70% Fe	
	Ferrous sulphate	37% Fe	Ordinary copperas, commercial grade
	Reduced iron	80-100% Fe	May be 20% ferric oxide
Cobalt	Cobalt sulphate		May be administered as a drench, as cobaltized salt, or as an ingredient in the ration

* As sources of calcium these products are useful in direct proportion to the calcium they contain.

considering this problem is obviously the phosphorus requirement of the cow. This determines eventually how much supplemental phosphorus may go into the meal mixture. The supplementary phosphorus needed will obviously be the difference between the cow's total requirement and that furnished by her feeds, roughage plus meal.

While it is true that good roughage consisting of at least half legume materials will contain about 0.20% of phosphorus, poor roughage comprising relatively mature non-legume plants cannot be depended upon to carry more than 0.10% phosphorus. The feed manufacturer

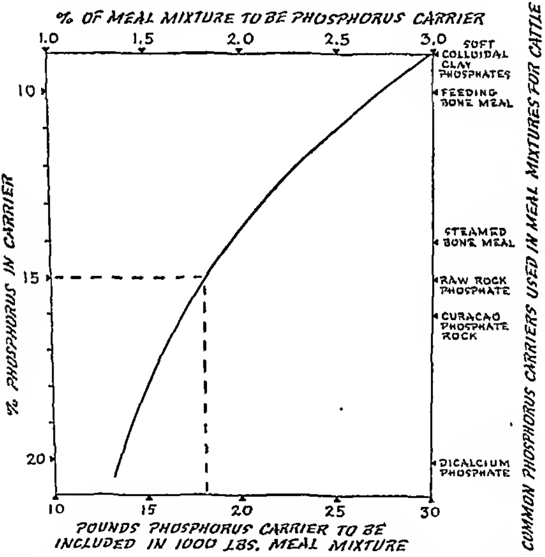

Fig. 13-1. *Pounds of phosphorus carrier needed in 1000 lb. meal mixture.*

in designing meal mixtures and the supplements of minerals to go in them must be prepared for the poor roughage feeder in order that all cases shall be covered

We can calculate the probable supplementary phosphorus requirement of a 16% protein dairy cow meal mixture by taking certain typical figures for size of cow, production, and roughage fed (see Table 13-2)

TABLE 13-2 *Supplemental Phosphorus Needed in 16% Protein Milking Cow Ration*

Daily requirement	
Maintenance of 1000 lb cow	10
Pregnancy demands	7
Production of 30 lbs of 4% milk	21
Total	38 grams
Supplied daily	
In 20 lbs average roughage	9
In 8 lbs meal before supplementation	19
Supplemental phosphorus needed	
In 8 lbs meal	10 gms
In 1000 lbs meal mixture	1250 gms
	2.75 lbs.

The quantity of phosphorus supplement that must be included will depend on the percentage of phosphorus in the carrier These amounts can be read directly from Fig 13 1 Example of a carrier having 15% P, 18 pounds will be needed in a 1000 lb mix, or 36 lbs per ton

The next problem is that of the fluorine The Canadian *Feeding Stuffs Act* gives permitted tolerances in ready to feed meal rations for cattle of 0 009%, or 90 p p m of dry matter This is equivalent to 40 grams of fluorine in a 1000 lb batch of feed

If the per cent of fluorine in the phosphorus carrier is known it is quite simple to calculate how much of such phosphorus supplement can be incorporated in 1000 lbs of a meal mixture so that the con

centration of fluorine will be 90 p.p.m. as permitted by the *Feeding Stuffs Act.* Fig. 13-2 shows that if 18 lbs. of a phosphorus carrier are to be used then it cannot contain more than 0.5% fluorine. If one had a phosphorus carrier with 0.8% fluorine then only 11.5 lbs. of it could be used per 1000 lbs. ration.

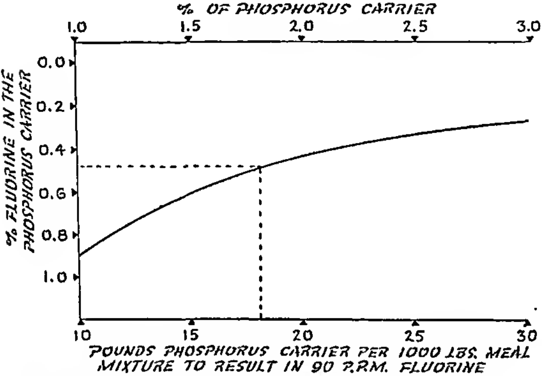

Fig. 13-2. *Maximum pounds of phosphorus supplement "tolerated" in 1000 lbs. of meal according to fluorine content.*

From these charts and further calculations we can make the following statements:

1. If the phosphorus carrier is restricted in amounts needed to meet the usual supplemental requirements, such carriers analyzing less than 0.2% fluorine can probably safely provide all of the supplemental phosphorus of the dairy cow meal mixture.

2. The maximum legal fluorine tolerance of 0.009% in the ready-to-feed meal ration insures safe meal feeding levels up to about 20 lbs. of meal per cow per day—enough for 60 lbs. of milk.

Miscellaneous Additives

Sweeteners, Binders, and Flavors. Sweetening agents such as molasses, dextrin, and sugar are often found in meal mixtures, and fantastic claims have sometimes been made as to their benefits Most such claims can be written off as sales talk and seldom originate from experiment stations Sweet taste does not appear to be of any significance either in coaxing animals to learn to eat dry rations more quickly or in getting larger feed intake

There may be some difference of opinion as to whether *molasses* is a basal feed or whether it should be classed as a special product Its nutrient contribution to the ration is sugar (The iron content of molasses is not usually of importance in the ordinary use of this feed) Its protein is negligible and it contains no fiber or fat Obviously this product is not freely interchangeable with other feeds of the basal category

Its more important contributions to the ration are due to its physical properties Because of its sticky nature it tends to reduce the dusty, powdery nature of some finely ground feeds In this role it often makes a feed mixture more acceptable to livestock It is doubtful if the sweetness of molasses stimulates feed intake initially, but once accustomed to a sweetened ration animals for a time may not relish unsweetened rations The effect of molasses in reducing dustiness can be obtained by slight moistening of a powdery feed with water But this is only effective at the time of feeding, since the feed dries out on standing Molasses, on the other hand, can be incorporated in the commercially prepared ration, does not adversely affect storage if not used in excess of about 10% by weight, and results in a dust-free mixture acceptable to animals Such mixtures more often than not contain products that may be powdery, and heavy, as well as being present in tace amounts only The problem of maintaining a homogeneous mixture in such cases is sometimes simplified by the inclusion of 5-10% of molasses If the feed is to be pelleted the molasses or dextrin helps to form a durable pellet

But molasses has another advantage, because of its distinct flavor

and aroma, it tends to mask or to dilute the flavors of other mixture ingredients. Thus the reactions of animals to the bitter taste of such feeds as rapeseed oilmeal, or ground buckwheat, or weed seeds; or the dry tastelessness of ground hay or oat hulls; or the peculiar aroma and flavor of malt sprouts may be modified by molasses. This use may be *all to the good* or *all to the bad,* depending on whether *we* are knowingly trying to utilize low grade products or whether it is *someone else* trying to disguise the presence of such materials in a ration in order to pass it off as being first quality.

Molasses in excess of 10% of the mixture invites the risk of producing a caked and perhaps moldy condition in bagged feeds. Ten per cent of molasses is enough to appreciably dilute the protein level of a mixture, and this dilutioo must be considered when this product is used either as an ingredient or when fed as a separate component of the ration, as when diluted and poured on poor rougbage.

In connection with the problem of preparing durable pellets it is worth noting that *sodium bentonite* may be of real assistance. Added at tbe rate of 2% to a ground feed or mixture it is innocuous nutritionally but facilitates the formation of a hard pellet that withstands the handliog and shipping to which commercial feeds are subjected.

Feed flavors are available io wide assortments. They are usually essential oils, whose distinctive aromas will permeate the feed into which they are mixed. Their presence can be detected months after the feeds are treated. It is often claimed that use of a flavoring material will aid digestion and stimulate appetite. Animals in normal health and, for one reason or another not self-fed, will usually eat voluntarily more feed than feeders are prepared to offer to them. The use of artificial flavors in "balanced rations" therefore leads to the suspicion that the mixture contains unpalatable ingredients; and since all high quality feeds are palatable to the stock for which they are normally suitable, artificially flavored feeds are often suspect in the eyes of better feeders.

On the other hand, veterinarians may use flavors to cover the taste and smell of drugs in some tonics. Such use of flavor, however, is quite a different problem, and of interest here only in cases where a feeder has been induced to feed one or other of the many patented

tonics or conditioners as a regular practice to prevent or to cure ailments real or imaginary, which he believes do, or may adversely affect his stock

Antibiotics represent another class of "foodstuff" that must today be considered in the formulation of livestock rations The nature of the action on the animal of the various antibiotics (aureomycin, terramycin, penicillin, etc) as ration components is still not entirely clear It is presumed that they affect the nature of the intestinal microflora It is well known that their use often results in faster gains of young animals (see also Chapter 8)

Many of the statements in the literature on antibiotics give erroneous impressions of the extent to which the use of these materials can be expected either to increase the rate of growth of the animal or to improve the efficiency of the ration consumed A recent review of the published papers dealing with the use of antibiotics for swine showed that on the average the gains of young pigs can be expected to be increased about 15%, and the efficiency of the ration improved about 5%, due to the inclusion of one or other recognized antibiotic There seems to be no particular advantage in using over 9 grams of antibiotic per ton of feed Another interesting finding in this survey was to the effect that if fish meal is a component of the ration there may be no response whatsoever from antibiotic Presumably this means that fish meal already contains as much of these substances as an animal is able to utilize efficiently

The necessary labelling of materials supplying antibiotics for feeding purposes is stipulated by the Canadian *Feeding Stuffs Act* as follows 'Antibiotic Feed Supplement is a feeding material used for its antibiotic activity It shall contain a single antibiotic or combination of antibiotics having growth promoting properties The name and amount of each antibiotic shall be declared on the label It shall contain a minimum of one gram of antibiotic per pound '

Drugs, especially arsenicals, are sometimes added to livestock rations because of their "antibiotic-like" action In other cases sulfonamides are employed in prophylaxis against coccidiosis (Sulfonamides are used only therapeutically with ruminants and swine)

Despite the fact of their approval and use in some countries, the

We cannot refrain from the comment that it would seem more sensible and appear to be economically sounder to curtail the production of excess fat on meat animals in the first place rather than try to salvage it by feeding it back to animal to produce, in turn, more surplus fat.

SUGGESTED READING

Feeders' Guide and Formulae for Meal Mixtures, Quebec Provincial Feed Board, E. W. Crampton, Secretary, Prov. Dept of Agr, Quebec, Que (1955).

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Wilder, O. H M., *Storage, Handling and Mixing of Fats Into Feed*, The American Meat Institute Foundation, 39 East 57th St, Chicago, Ill, Cir No 11 (1954).

CHAPTER 14

Roughages

General Characteristics of Roughages

ACCORDING TO the definition adopted in this book roughages are feeds carrying more than 18% of crude fiber. In practice, most roughages are forages. In applied feeding, feeds of this classification are involved primarily (though not exclusively) in rations of herbivorous animals. With such animals they play a physiological role in addition to that of supplying nutrients.

As with other feedstuffs, roughages can be partially described nutritionally in chemical terms. However, the concentration of many of the nutrients found in roughages is of minor importance in their use. For example, forages are good sources of several members of the Vitamin B family, but since the microorganisms of the digestive tract of herbivorous animals normally synthesize all of the B-complex Vitamins the animal needs, the extent of their presence in the forage is of no particular consequence. Insofar as the mineral nutrients are concerned, their abundance or relative deficiency in different forages is not ordinarily an important factor in the choice of forage fed. What is fed is what is grown, in the majority of cases, and the deficiency with respect to mineral elements is corrected by supplementation in the form of mineralized salt licks, or by mineral fortification of the meal mixture, if such is also a part of the feeding program.

Nor does the herbivor need to depend on the ration for any particular assortment of amino acids, though there is a minimum of protein equivalent required. Here, again, microorganisms of the di-

gestive tract synthesize all of the amino acids needed by the host animal, apparently requiring only a source of nitrogen and of carbon from the host's ration

In the final analysis, therefore, roughage is likely to be economically and nutritionally important in the ration as a source of bulk, energy, and protein, and *the final limiting factor in its nutritional value is its available energy yield*

Concentration of Nutrients in Roughage. Compared to concentrate feeds, most roughages on a dry matter basis yield no more than three-quarters as much energy (TDN) Hence the nutritive picture of roughages when measured against animal requirements is often obscured Fig 14-1 is an attempt to depict the digestible protein, calcium, and phosphorus concentration in roughage as compared to that needed in the complete ration of an adult cow The numerical values of the index of concentration were obtained by dividing the pounds TDN required daily by the cow into the D C P (lbs), the calcium (gms), and the phosphorus (gms) required The quotients were then multiplied by 1000 for protein and by 100 for Ca and P The resulting figures have no significance in themselves but if we calculate corresponding figures for some feed, comparison of the indexes for the requirement and the feed will tell the extent to which that feed would meet protein, Ca, and P needs of the animal *if enough of the feed is eaten to meet the TDN requirement* Such indexes have been calculated for five types of roughage

1) Typical mixed grass pasturage at an early maturity stage
2) Excellent red clover hay of less than 26% crude fiber
3) Low quality overripe clover hay
4) Excellent early bloom timothy
5) Low quality fully mature timothy

We can see from Fig 14-1 that, except for low grade non legume hay, either fresh growing pasturage or cured hay will carry enough protein for maintenance of dairy or beef cows if they will consume enough of the forage to fully meet their maintenance energy needs However, the milking cow, under the same conditions, will be short of protein even on a good non legume hay As to calcium, only low

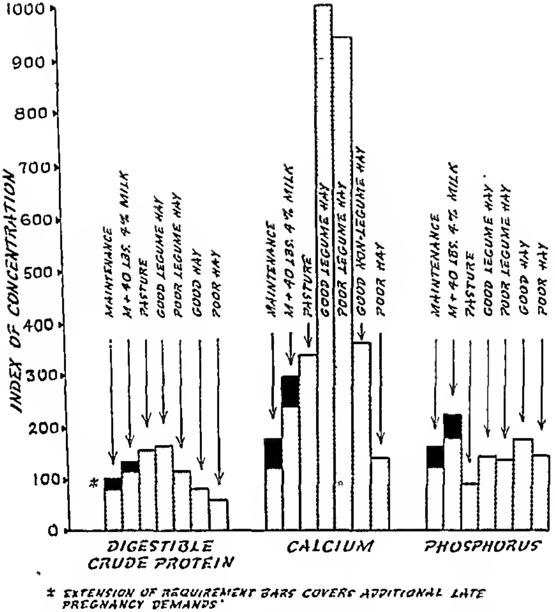

Fig. 14.1. *Showing concentration of protein, Ca, and P, relative to TDN in Roughages.*

grade non-legume hay is deficient relative to the energy of the forage. With phosphorus, however, none of the roughages considered is adequately supplied. In practice, this deficiency means that the milk cow meal ration will always require supplementary phosphorus (and salt); but since all sources of phosphorus also carry calcium, the relative shortage with low quality roughage will be made good through the phosphorus carrier. Some augmentation of protein will have to be arranged where non-legume hay is fed.

Significance of Energy of Roughage. In the final analysis the major factor in the use of roughages as feeds for milking cows is, therefore, how much roughage will the animal consume relative to her energy needs? To the extent that less roughage is eaten than is necessary to meet energy requirements, meal feeding will be called for The concentration of nutrients of such a meal mixture will depend both on the quantity of meal to be fed and on the specific nutrients it must furnish

It is interesting and significant to note that Dr Folke Jarl of the National Animal Experiment Station, Royal Agricultural College at Ultima, Uppsola, Sweden, uses the concentration of available energy (as starch equivalent) in 100 lbs of dry matter of roughage—a figure somewhat comparable to % TDN—as the index of roughage quality He states, 'The highest possible use of forage (pasture, ordinary hay, dehydrated hay, and grass silage) will depend on the concentration ratio of this forage in relation to the concentration ratio of other feeds (as concentrates) Protein content of forage need not be a limiting factor in its use, because the protein content of the concentrate mixture can be varied almost at will the concentration ratio is the limiting factor in feeding large quantities of forage to high yielding cows *

This way of thinking about roughages—that they are primarily of use as sources of available energy—puts a somewhat unorthodox interpretation on the generally used classification of the hundreds of individual products having sufficiently different proximate analyses and/or botanical characteristics to be listed as different feeds If the cow does not care which one she eats, then, in the interests of simplicity and realism, we might better classify roughages on the basis of their yield of available energy than on the basis of protein Before going further with this argument, however, we should look briefly into the factors that influence the useful energy of roughages

Form in Which Roughage Is Fed

Whether or not we can consider pasturage, silage, and dried forms of the same plant as nutritionally equivalent on a dry basis is indi-

* *Proceedings Sixth International Grasslands Congress* V 11 p 1179 (1952)

cated by data taken from Morrison's tables of feed composition. For products made from comparable alfalfa he gives figures as follows:

	TDN	DCP
Fed green	60.7%	14.2%
Sun wilted silage	58.7	12.2
Molasses silage	60.2	12.7
Sun cured hay	56.1	11.1

These figures suggest that in the harvesting of hay, losses occur which reduce the digestibility of the final product. Moore and Shepherd have summarized studies at the Experimental Farm of the U.S.D.A. at Beltsville, Md., from which it appears that for field-cured second-cut alfalfa, one may expect from the condition at cutting to the condition as fed, percentage losses of:

Leaf	35%	
Dry matter	20	(including leaves)
Protein	29	

Stemmy Hay. These figures do not mean that such hay will be "all stem." If *as cut* the crop carried 55% leaf by weight, the hay *as fed* would carry 34% of leaves and 66% fine and main stem. This proportion is about the leafiness of excellent clover hay.

These losses actually reduce the TDN of the hay as finally fed *much less* than we might suppose. If we assume that the crop as cut carried 55% leaves, and if we use a TDN typical value of 57% for alfalfa leaves, and of 43% for alfalfa stem meal we can calculate:

$$(55 \times 57\%) + (45 \times 43\%) = 50\%$$

as the expected TDN for the hay without any loss of leaves. Similarly, we might calculate for the crop after 38% loss of leaves:

$$(38 \times 57\%) + (66 \times 43\%) = 47\% \text{ TDN}$$

Leaf loss will also involve a loss in digestible crude protein, but this can be made good, if necessary, through the meal mixture. And thus one is forced to the conclusion that while a 20% loss in dry

weight in the harvesting of hay may be *economically* important, the change in energy value per pound of feed may not be excessive It amounts to something like 6% in the example case This small loss is because most of the energy from the roughage comes from cellulose or hemicellulose, which is not reduced in proportion through the harvesting losses

The facts are that the energy values of poor quality hay are not enough below those of good hay to be the major cause of the poor results so often obtained in practice with poor hays (see Table 14-1)

TABLE 14-1 *Per Cent of TDN in Good and Poor Hay (90% dry matter basis)*

	Good quality	Poor quality
Alfalfa	51	49
Clover	56	52
Clover and timothy	50	47
Timothy	53	49

Recent experiments indicate that a part of the cause of the poor results with low quality hays is traceable to their failure to support a maximum microflora in the rumen As a consequence digestibility of crude fiber suffers The more serious effect, however, is a secondary one *as rumen microflora activity declines, roughage consumption declines* Since a cow obtains from half to practically all her TDN from roughage, any decrease in consumption is serious

Perhaps we have said enough about the peculiarities of roughage to establish the fact that the feeding value of forages, and in particular of hays, depends very largely on the quality of the product However, the term *quality* is often purely relative, and it may be well at this point to consider briefly the problem of hay grading

Hay Grading

For those products that are composed essentially of one kind of plant, the name (such as timothy, alfalfa, clover) is quite definite in

its meaning However, there are other names used for hays that are much less specific *Grass hay*, for example, includes all of the grasses made into hay other than those that are named according to species Thus, for example, grass hay may include edible sedges and rushes as well as the mixtures that are sometimes harvested from permanent pastures or from meadows that have been unplowed for some time and which have reverted to the combination of indigenous plants of the area

Mixed hay is a catch-all term and includes all mixtures that consist at least 50% of plants for which standards have been separately established Thus, for a product that was 52% timothy with the balance made up of other grasses, the term *mixed hay* would likely apply Sometimes mixtures are given specific names such as "mixed clover and timothy" or "mixed alfalfa and timothy", and such terms apply particularly where such mixtures were intentionally seeded

Within such names, grades are established to describe the quality of the product The particular numerical rating of different grades is of no consequence to us at the moment It will be interesting, however, to note those factors that determine the grade or quality of the different hays

One of these is *color* It is generally assumed that green color is an indication of the feeding value of a hay The presence of a large amount of green color usually indicates that the hay was cut early, was properly cured, will be palatable, and that it is free from dust and mold In many cases also, the intensity of green color is correlated with the amount of carotene present in the product

Livestock feeders frequently question whether as much dependence on color as an index of quality is justified as graders imply Recent evidence indicates that the preference of cattle for different types of hay does not seem to be correlated with color, and we know that the preference of cattle for forage is a reasonably good index of its energy value

The extent of the *foreign material* in the hay is another factor in grading for quality Foreign material includes weeds, grain straw stubble, thistles, etc, most of which has little or no feeding value Feeding tests at the U S D A indicate quite clearly that the proportion

of hay refused by cattle is correlated with the extent of the foreign material in it The cattle refused almost twice as much of the offered hay in grades that contained appreciable quantities of foreign material as they did of the same sort of hay containing relatively little of such admixtures

Leafiness is a grading factor in all classes of hays Leafiness is used as a grading factor because it reflects the protein content of the hay Leaves contain from two to two and a half times the concentration of protein as does the stem of the same plant This is true regardless of the kind of plant It is the leaves also that are richest in carotene calcium, and phosphorus Leafiness is much dependent on the stage of maturity of the plant when it was harvested The more mature the plant when cut, the more easily are the fine leaves lost in handling Consequently, it is generally true that hays harvested from plants cut at a relatively immature stage will retain a greater leafiness in the crop as fed than will plants cut when more nearly ripe

On the other hand, *stage of maturity,* though it does have a considerable influence on the feeding value of hay, is not normally a factor included in grading hay It has been assumed that leafiness and color, which are affected by stage of maturity, thereby become indirect indices of maturity of the plant at cutting time

Actually an idea of the maturity at which most of the grasses were cut for hay can be rather easily determined If the portion of the stem above the top joint can be pulled out easily from the sheath and the lower part of this portion is found to be dark because it was tender and still growing when cut, the plant was cut before bloom In the development of the grass, growth takes place at this point until just before it begins to bloom If the top portion of the stem cannot be pulled out, then the maturity can be determined by rubbing the heads in the palm of the hand and examining the maturity of the seed Unfortunately, there is no satisfactory way of determining from the cured hay the stage at which the legumes were cut Sometimes evidence can be found in the presence of flower petals that show color, and in the case of very late cutting, the presence of seed pods

Maturity affects the protein and the fiber content of all kinds of

hay, the protein content decreasing and the fiber content increasing with advancing age.

Though potentially useful, hay grading has never been much depended on by feeders to describe quality of roughage. In practice, feeders commonly refer to their hays as *good* or *poor*. These terms, as thus used, are relative, and are often employed to compare samples without reference to the excellence of either one in respect to feeding value. Thus, two lots of hay may both be of low feeding value but one still referred to as *good* as compared to the other. It seems in order therefore to define what constitutes *good* hay in terms that have some significance as to feed value.

What Constitutes Good Hay

Maturity at cutting. As we have already indicated, maturity at cutting is a most important factor in hay quality, and we cannot too strongly emphasize that, regardless of the species of plant, the best quality hay can be made only from a crop cut well before maturity. The reason that stage of maturity is such an important factor in hay quality as we pointed out is that it determines the proportion of leaf to stem present in the product. The stems of forage plants are invariably of low feeding value. Every feeder recognizes that straw, which is almost entirely stem, is of low feeding value, while, on the other hand, cereal grain crops cut before much stem develops can be made into excellent hay.

The rapidity with which the stem increases with maturity is such that a delay in cutting of only a few days may actually mean a large loss in feeding quality of the hay made. This is strikingly illustrated in data from experiments at Macdonald College shown in Table 14-2.

It was worth noting that in the 11 days from the time the heads were forming to the early bloom stage there was a 33% increase in the weight of coarse stems in the crop, and a corresponding decline in the proportion of fine leafy material.

We should also point out that all shallow rooted crops used for hay are likely to be at ideal maturity for cutting during a time

TABLE 14-2 *Proportions by Weight of Leaves and Stems in Hay From Red Clover According to Stage of Maturity When Cut*

Stage of maturity when cut	Days between stages	% leaves and fine stems	% main stem
Prebudding	—	75	25
Budding	5	51	49
Early bloom	11	34	65
Full bloom	10	30	70
Heads brown	18	25	75

when there is poor curing weather We should expect this result in view of the fact that the very thing that makes for high feeding value in these hay crops is surface moisture As soon as the moist conditions change to drier and warmer ones, the production of new leaves ceases and the plant starts to make stem and seed It is this situation which is behind the justification for the use of grass silage or of artificial drying schemes as a means of preserving the high feed value of forage crops raised on the farm

In connection with the hay grading schemes that are used, we pointed out that stage of maturity is not one of the factors directly considered There is doubless justification for ignoring this factor in the case of hays to be sold commercially, but most of the hay fed to livestock is grown on the farm where it is fed Consequently, there is no problem in knowing the stage of maturity of any particular hay From the farmer's standpoint, stage of maturity becomes a particularly important criterion of when to cut his hay crop It is also an index of the quality or feeding value he can expect in the final product

Kind of Plant. Legumes can be made into hay of higher feeding value than grain plants or non legume grasses The reason is almost entirely the difference in proportions of leaf to stem The young tender leaves of all common plants used for hay are apparently of about equal feeding value for herbivorous animals Legumes, however, have more leaves per pound of dry plant than grasses At the

stage of maturity necessary for the best hay, the leaf in timothy is about 30%, in clover 40%, and in alfalfa 55% of the dry weight of the plant

Mechanical Losses in Curing. A third factor in the quality of hay is the loss in curing We have already pointed out that this loss, in terms of percentage, is sometimes more important economically than nutritionally It is nevertheless true that the parts of the plant lost in greatest quantity are the leaves, and since this loss is one factor in determining how much of the crop will be eaten by livestock, it obviously affects the quality of the hay

Good Hay Defined. In order that the feeder may have some practical basis of judgment in evaluating the quality of his hay, the following might be used as a standard for *good* hay It is expressed in terms of the proportion of leaf in the total weight of the dry feed

Timothy	28%	leaves
Clover hay	35%	"
Alfalfa hay	50%	"

In addition to being leafy, good hay should be cut in the very early bloom stage, cured rapidly, and taken into the barn without being wet Such hay will be of high feeding value, because it will be rich in protein, high in minerals, high in Vitamin A, but, above all, the energy yield will be maximum for the type of feed in question Hay that does not meet these specifications will not be top quality from the standpoint of nutritional value, regardless of any other considerations

Low Grade Roughages

What we have said so far applies to crops fed as pasture, grass silage, or the ordinary hays There is, however, another group of roughages, which, while not of as much importance as hay or silage, nevertheless represent a type of feed which is often available on the farm, and though of low energy value is fed as a means of making

some use of it Such roughage is not ordinarily fed to producing stock Indeed, it is often made available in stacks or racks to which cattle on maintenance rations have ready access The feeds of this group are not important in determining the nature of a suitable meal mixture (if any) to be fed also to such animals

In this subgroup there will be some of the poor quality hays made from miscellaneous grasses and often badly contaminated with weeds Some hay crops that have matured to the seed stage will also be involved, as well as some prairie hays Standing still below these will come the straws made from the cereals, threshed hays, and finally the sedges and swamp grasses that are harvested in some cases as a means of having roughage of some sort available under adverse conditions The best of the products in this low energy group yield only about three-quarters as much energy per pound of dry matter as do the standard roughages, and some of them may be even lower in relative value None of them can be depended on as sources of Vitamin A and usually the protein content will be almost negligible —perhaps 1 or 2% of total crude protein

Lignification. These low energy roughages are not necessarily low in cellulose or hemicellulose, in fact they are likely to be higher in crude fiber than the standard hays or silages The chief reason for their low feeding value, in most cases, is traceable to a lignification of the cellulose It is believed that lignin is a protective coating laid down in the plant structure in association with cellulose to give it rigidity and durability Lignification starts after the growth in a given part of the plant ceases In other words, it is one of the changes that occur in the plant structure with advancing maturity Experiments have indicated that lignification starts at the bottom of the stem and proceeds upward, following along behind the areas that have ceased to grow

Lignin contains a phenolic nucleus, and it is perhaps this feature that protects it from bacterial attack Whatever the specific cause, we know that lignified cellulose is attacked very slowly, if at all, by the microorganisms of the intestinal tract Examination of the residue of roughages consumed by ruminants shows that the only particulate

portions of the plant tissues that are found intact in the fecal material are those that stain with phloroglucinol, indicating that they are lignified *

Not only do the stems of plants become lignified with maturity, but the leaves and the husks and even the hulls of grains as barley and oats are thus protected Some plants, such as coarse rushes and sedges that appear to have no stem distinct from leaf, are also highly lignified and, consequently, their cellulose is not easily digested by the animal

There is no evidence that the lignification of plant tissues is a deterent to their initial consumption It seems rather that the failure to consume such low-grade roughages in amounts equal to that eaten readily of high-grade forage is a reflection of the decreased activity of the microorganisms of the rumen (and of the caecum, where the caecum is functional) Whatever the cause, there is no dispute among feeders that livestock consume high quality fodders better than low-grade roughages

Some improvement in the consumption of low-grade roughages appears to be possible by supplementing such rations with additional protein and with a mineral mixture It is believed that such supplementation provides nutrients that are deficient or unavailable in the roughages, but which are required for the full activity of the microorganisms Under such supplementation it has been found possible to obtain about as much TDN from some of the low-grade products, such as corn cobs and straws, as is obtained normally from average quality hay We do not know the extent to which this represents a more active attack on the roughage by microorganisms, except by inference

An Energy Classification of Roughages

If we attempt to group roughages according to yield of available energy (TDN) we find that practically all of the well-known ones can be fitted into one or another of six subgroups that differ in units of 5% of TDN (see Chart 14-A) We can give an indication of what

* See Drapala et al *Sci Agr* V 27, p 36 (1947).

CHART 14-A *Classification of Roughages on an Available Energy Basis*

% TDN (air dry basis)	Forages	Average daily voluntary intake per 100 lb wt cow (lbs)	Probable special supplementation needed for producing animals
60 65	Well grazed actively growing pasturage	3 0 or more	phosphorus
55 60	Hay crop silages, including cereals corn silage (dough stage)	3 0	TDN * Phosphorus
50 55	Properly cut and harvested hays from reasonably pure stands of alfalfa, clover, timothy, or mixtures of them Average corn silage	2.5 3 0	TDN, Phosphorus
45 50	Hays from nearly mature stands of other wise suitable hay crops (see above) Dormant pasturage	1 5	TDN, Protein, Ca + Phos
40 45	Hays from miscellaneous grasses often carrying weeds Same hay crops in seed Prairie hays	less than 1.5	TDN, Protein, Ca + Phos
35 40	Straws from cereals threshed hays sedges and swamp grasses	less than 1 0	TDN, Protein, Ca + Phos

* For above average milk production

products belong in each of these subgroups in general terms with sufficient accuracy for the practical use of our table We have also attempted to indicate the approximate voluntary consumption that can be expected by cattle according to the quality of the roughage Finally, we have included a column in which are noted major deficiencies that are likely to need correction when the roughage consists of one or more products of the group indicated

In general, well-grazed pasturage, which is actively growing, will be

in the top energy class among the roughages; and insofar as energy yield is concerned such products may be the equivalent of some of the light bulkier grains such as poorly filled oats, or some by-products such as wheat bran. If these products are analyzed chemically, the pasturage will show a higher crude fiber content than the grains or by-products with which they may be comparable as to energy. This result merely illustrates the fact that in about 25% of the instances recorded in textbooks on feed consumption and utilization the crude fiber portion of the feed is higher in digestibility than is the nitrogen-free extract component. Consequently, it does not always follow that feeds with the higher fiber content are also lower in available energy.

Forage belonging in this top grade is readily eaten by all herbivorous animals, and grazing dairy cows will consume up to 150 lbs. per head per day—equivalent to nearly 50 lbs. of air-dry feed or 30 lbs. TDN. Obviously, such material requires no supplementation for average production conditions.

Hay crop silages and corn silage from corn cut in the dough stage are but a little less valuable than the pasture herbage described above. Any decline in energy yield will be due to inclusion in the silages of a greater portion of stemmy lignified tissue. This material the animal normally avoids during grazing. Present day management recommends that not over half the total roughage for a milking cow be supplied in the form of silage. It is evident that replacing a part of the hay with an equivalent quantity of silage on a dry basis does not reduce the feeding value of the total roughage allowance. Actually, there is probably more feeding value in one pound of dry silage material than there is in one pound of most of the hay crops fed.

It is with feeds belonging in the next two categories that most of the feeding problems arise. These categories cover the majority of typical dry roughages that will be involved in the feeding of producing herbivorous animals—animals that require additional energy and perhaps additional protein beyond what the roughage allowance will supply. Category No. 3 will include all of the high quality hays made from legumes and also a few of those hays that are made from early-

CHART 14-A *Classification of Roughages on an Available Energy Basis*

% TDN (air dry basis)	Forages	Average daily voluntary intake per 100 lb wt cow (lbs)	Probable special supplementation needed for producing animals
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55 60	Hay crop silages including cereals corn silage (dough stage)	3 0	TDN * Phosphorus
50 55	Properly cut and harvested hays from reasonably pure stands of alfalfa clover timothy, or mixtures of them Average corn silage	2.5 3 0	TDN Phosphorus
45 50	Hays from nearly mature stands of otherwise suitable hay crops (see above) Dormant pasturage	1 5	TDN Protein Ca + Phos
40 45	Hays from miscellaneous grasses often carrying weeds Some hay crops in seed Prairie hays	less than 1 5	TDN Protein, Ca + Phos.
35 40	Straws from cereals threshed hays sedges and swamp grasses	less than 1 0	TDN Protein Ca + Phos

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cut non legume hay crops Non-legume hay, however, in order to get into this category, will have to be exceptionally good for its type We should also place in this category average corn silage

The fourth category will include in general the non-legume hays that might have got into the category above except for the fact that they were too mature when harvested to be as highly digested as they might have been earlier Here, also, should be classed what might be described as dormant pasture This will be pasturage available during the dry periods of summer when there is little growth, and also winter pasture, which really represents grasses cured on the root and harvested by grazing

In the practical use of roughages the differences between categories 3 and 4 will be more traceable to differences in the quantities animals will consume voluntarily than to differences in chemical composition Here we note that whereas forages belonging to category 3 will usually be consumed voluntarily by cattle at a rate from 2½ to 3 lbs daily for every 100 lbs of weight of cow, those of category 4 are likely to be consumed in quantities not much exceeding 1½ lbs daily per 100 lbs liveweight of cow It is this difference in the quantity consumed that is the major factor in determining the quantities of meal mixture that must also be supplied in order to meet the full energy requirements of producing animals

With regard to the last two categories (5 and 6), we are normally dealing with a feeding practice intended primarily to maintain non producing stock over a winter period, or at some other time when their energy requirement is relatively low These materials are normally cheap and are fed as a means of converting them into something useful Their efficiency is not a major consideration

The significance of this energy classification of roughages will become more evident when the problem of meal mixture formulation is discussed in a later chapter of this book

Nutritional Liabilities in Forages

We have already noted the possibility of certain deficiencies in forages, and that in general the problem of deficiencies is not serious,

because it is usually economically feasible to make good deficiencies of mineral elements and of such vitamins as are needed by herbivorous animals through supplementary licks or by inclusion of the nutrients in meal mixtures that are to be fed with the roughage The problem is chiefly one of recognizing the existence of deficiency

Ideas of what may constitute a deficiency may vary considerably, depending on experience in different localities For example, it has been tentatively recommended that *copper* be included in a mineral supplement at a level of 0 3% On the other hand, in certain peat soil areas of Southern Florida, it has been found necessary to use as much as 1 25% copper in the mineral mixture to make good the deficiency in that locality Also, we should point out, that the concentration of mineral elements in a mineral supplement must be related to the extent of the consumption of that mineral mixture Here we have the problem of the voluntary consumption of mineral mixtures offered free choice, as well as the problem of mineral mixtures included in meal rations at a fixed concentration Obviously, if very small allowances of meal are to be offered to cattle, then we shall have to include higher concentrations of minerals to meet a mineral deficiency than we would have to with more liberal grain feeding

In the practical use of roughages in livestock feeding, it is probable that deficiencies of mineral elements can be rectified by proper supplements There are a few minerals found in forages that are beneficial when ingested in small amounts, but become toxic at larger intakes

Arsenic is such a mineral, introduced into the ration in trace amounts it is a growth stimulant It has also been reported that as little as 25 p p m of arsenic in a ration may counteract the toxic effects of chronic selenium poisoning induced by the consumption of selenium-containing forages

*Fluorine** is another mineral element that may have both beneficial and toxic effects, depending on level of intake Insofar as the beneficial intakes are concerned, the levels are certainly below 10 p p m on the basis of total dry matter of food consumed The more serious problem with this mineral is related to its presence in forages in

* See also Chapter 13

amounts of 30 40 p p m or greater It is ordinarily of local concern being confined to areas in the vicinity of industrial plants where fluorine is among the effluents from the manufacturing processes It is not unusual to find forage in such areas carrying well over 100 p p m of fluorine Experimental evidence indicates that adult cattle can tolerate for at least 3 years intakes up to 1 5 mg/kg of body weight, and for rough figuring this suggests that forage dry matter carrying more than 50 p p m must be classed as unsatisfactory if such material constitutes the entire dry matter intake

Toxicity in this case must be carefully interpreted The adverse effects of excessive fluorine intake do not appear abruptly and indeed, there may be no clear-cut symptoms that are unmistakably the result of the fluorine ingestion Usually when cattle ingest feed carrying appreciably more than 25 p p m of fluorine there will eventually be clinical symptoms of dental fluorosis Loss of enamel and tooth staining are regularly observed, the teeth may show uneven wear and in some cases become carious These symptoms are of themselves of less importance than the disturbance in energy metabolism It seems probable that fluorine ingested in amounts greater than can be immobilized in the bone or excreted promptly in the urine may become incorporated into one or more of the enzymes involved in the Krebs cycle As one result, citrate cannot be metabolized to isocitrate Interference in this path of energy metabolism not only decreases the energy available from the feed consumed but probably tends to lead to greater synthesis of acetoacetic acid some of which in turn may be converted to acetone for elimination Thus there is the distinct possibility that chronic fluorosis may be one of the causes of secondary acetonemia In any case chronic fluorosis appears to be relieved by removal of fluorine from the ration, and symptoms of semi starvation induced by failure of energy metabolism eventually subside What may be called *acute fluorosis* is not normally induced by the consumption of fluorine-containing forages

Molybdenum toxicity must be considered in terms of the copper level of the diet The exact toxic action of molybdenum is unknown but the experimental evidence suggests that it in some way interferes

with copper utilization, and that the final result is probably a disturbance in copper rather than in molybdenum metabolism Excessive molybdenum intake (16 p p m or more) is one of the few conditions that induces persistent scouring with ruminants

Molybdenum toxicity in cattle has been prevented with forages containing up to 5 p p m of molybdenum by the administration of 5 p p m of copper As the molybdenum content of the forage increases, the proportionate amount of copper necessary to counteract its effects increases so that with 10 p p m of molybdenum, 20 p p m of copper is needed

Nitrates are sometimes found in some forages, particularly those made from cereal crops Oat hay, for example, having more than 1 5% potassium nitrate will be toxic to cattle The toxicity is thought to be the result of nitrate becoming changed in the rumen to nitrite, with subsequent formation of methemoglobin

Forages from a few areas have been found to contain *selenium* Any soils containing 5 p p m of selenium are potentially dangerous, as crops grown on them will also contain dangerous levels of this mineral The chronic condition of selenium poisoning is often referred to as *Alkali Disease* and the acute condition as *Blind Staggers* Any forage that contains 5 p p m of selenium fed over a period of time will result in chronic poisoning to livestock The mechanism of selenium toxicity is still unknown Experimentally it has been shown that the ingestion of small amounts of arsenic will counteract the effects of chronic selenium poisoning in cattle The problem, however, is one that must be treated carefully, and we can give no general recommendations

Fortunately the problem of the presence of potentially toxic materials in forages is not a general one, and, therefore, does not concern the great majority of feeders who use roughages Those who may be in hazard zones will, of course, be well-advised to familiarize themselves with the problems and treatments

Practical Aspects of Pasture as a Feed

On many farms pasture forage is one of the cheapest feeds available during certain times of the year There is much misunder-

standing, however, as to how best to use this feed A few comments may be useful in this connection

Young, rapidly growing, leaf growth is rich in protein (about 20%) As the plants mature the protein content drops until the dried grass may carry no more protein than straw. Heavy grazing keeps the grasses immature and hence at their highest feeding value

Pasture becomes too mature to yield its maximum value as soon as the plants begin to head out If such growth is mowed down, it will not be wasted, for grazing stock will eat it quite readily Mowing encourages renewed growth of leaves provided, of course, there is moisture

The feeding value of pasturage is increased by the presence of clover In some areas Wild white clover will come into many permanent pastures if they are grazed heavily enough to keep down the tall growing species

Young grasses and legumes grown on lands well supplied with phosphorus usually contain enough of this nutrient for grazing animals when pasture supplies the entire ration The phosphorus content, however, declines with the maturity of the forage, which then may not supply enough phosphorus for grazing stock In general, animals replenish depleted phosphorus stores while they are on pasture Consequently, it is desirable to feed a phosphorus-containing mineral mixture to all breeding stock while pasture is their principal feed Satisfactory consumption of such a mineral mixture is assured chiefly because of its salt content Consequently, no other sources of salt should be provided

In order to graze pastures more efficiently, rotational grazing in some form is a sound principle Even dividing the area into two portions and alternating from one to the other will permit alternative periods of heavy grazing followed by a short recovery period Rotational grazing is of no value however unless the growth is kept down by close grazing

Straw as a Feed

Straw from the cereal grains, particularly from oats, is readily eaten by all classes of cattle and is, in some districts, a regualr part

of the ration of low producing or dry cattle Its inclusion in *production rations* is often false economy because the net energy it will supply to the cow is small Its maximum value will be obtained by feeding it along with high quality legume hay In some areas it is customary to seed clover with a grain crop This practice results in appreciable amounts of clover in the grain at harvest time and eventually in the straw Such straw—really a mixture of straw and clover hay—has considerable feeding value and is quite a different product from the straw of a clean grain crop Used as one feed per day such material is probably equal to average timothy hay

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SUMMARY OF SECTION III

In Section III we have been concerned with another part of applied nutrition—the nature of feedstuffs. We have seen how diverse they are; and in order to systematize our tbinking about the concentrate feeds we have suggested a functional grouping for them based largely on protein content. Origin as to plant or animal source is also involved in a sub-grouping of some high protein products. The grouping according to protein is convenient and practical, because one of the first considerations in ration formulation is protein level, which is attained in practice by selecting feeds in accordance with their protein contents.

Such a classification disregards the origin of most feedstuffs, and so we lose sight of the fact that plant seeds may yield, in the course of milling, several feedstuffs, each belonging to a different functional group. For example corn, itself a basal feed, is the parent product of two other basal feeds, hominy and bran; and four protein concentrates, gluten feed, gluten meal, germ meal, and distillers' grains. Similarly, wheat yields the basal feeds: middlings, shorts, and bran; and the protein concentrates: germ meal and distillers' grains. In neither case are the basal feeds interchangeable with the protein supplements; whereas both the basal feeds and the high protein by-products of the one grain may be substituted for those of the corresponding classification from the other grain. The distinction as to origin may, in the case of some feeds, be significant, but more usually it is of little importance nutritionally.

This functional grouping by bringing together feedstuffs that serve roughly similar purposes in the ration facilitates the preparation of pattern formulae for meal mixtures within which a wide variety of different feeds may be used alternatively to give combinations of essentially equivalent feeding properties This, of course, does not mean that individual feeds of a particular category have no unique properties It means rather that broadly speaking basal feeds, for example, are in the mixture *primarily* because of their *energy* content and the protein concentrates because of their *protein* Protein concentrates fall into two sub-categories, because those of plant origin in general differ in amino acid content from those of animal source, and so on The special properties of the individual feeds within categories may be of no nutritional importance in some cases, in others their limitations are minimized by using several feeds In the long run, however, if a feedstuff can be correctly assigned to its appropriate category in our feed classification scheme, it can be used in ration formulation without risk of adverse consequences, even though full information of its unique properties is not at hand at the time

Roughages are distinguished from concentrate feeds by their fiber content concentrate feeds, in general, carrying less than 18% of crude fiber Of particular importance with roughages is their yield of useful energy, and thus TDN becomes the basis of their final grouping

Therefore we can assign feedstuffs to their appropriate main functional categories if we know their crude protein and their crude fiber contents Information as to whether they are of plant or animal origin will enable further sub-classification of certain high protein concentrate feeds Information as to the botanical makeup and the stage of maturity at harvest of a forage will permit a reasonable estimate of the probable TDN, and hence of the roughage sub-category to which it should be assigned

To make the best use of different feeds requires that we know as much as possible about their peculiarities and special characteristics To this end we must ultimately examine each feedstuff critically in order to make the fine adjustment that in special cases may make

one combination preferable to another. For up-to-date detailed description and performance of individual feeds the student must consult the scientific literature. Such information will not alter the basic concepts discussed in this text, but rather will make them more useful in the practical, albeit complicated, problems of tailoring rations to given specifications.

SECTION IV

RATION FORMULATION

This section differs from the three preceding it in several respects Section I dealt specifically with the definition, and, in some instances, with the biological significance of a number of terms and expressions used in applied nutrition We tried to crystalize the real meaning of such entities as TDN, coefficients of digestibility, proximate analysis, biological values, *etc* and thus to clarify their usefulness as descriptive terms The subject matter is important in its own right Precise understanding of these terms is essential to their correct application Failure to recognize their limitations, no less than erroneous assumptions as to their meanings, or the assignment to them of attributes which they in fact do not at all or only in part possess, lead only to difficulties in applied nutrition

In Section II we gave critical appraisal of feeding standards *as quantitative statements of the requirements of animals for energy and for several of the nutrients which the feeder must consider in compounding livestock rations Obviously this is also of importance in its own right Without an understanding of the nature of such standards and of the inherent peculiarities of the data they contain, we cannot hope to make either full or exact use of them in ration formulation*

Section III covered a third, and, again, a somewhat autonomous

part of applied nutrition—a consideration of the nature of feedstuffs not so much of individual feeds as of groups of nutritionally similar products the members of which in feeding practice are to varying degrees interchangeable It was in this section that some of the significance of the discussions in Section I should have become evident For example the choice between oats or barley for use in a given ration might depend on an accurate knowledge of any real difference between them in their yield of useful energy to the animal In view of the limitations of TDN as brought out in Section I it should be clear that dependence exclusively on this measure as descriptive of the useful energy of these two feeds could lead to ill-advised substitutions Or again the discussion of forages should have served to emphasize the uncertainties of the proximate analysis in whole or in part as a measure of the nutritional value of many feedstuffs

But it is in Section IV that the facts figures and philosophy of the three previous parts are integrated into our ultimate objective—the formulation of nutritionally adequate rations or of feed mixtures of defined nutritive properties It is as components of such mixtures that most feeds are put to work Their selection and the extent of their inclusion in mixtures will obviously depend in part on what nutrients they contain and in part on what we need to provide the animal with

The translation of feeding standards into terms of ration formulae is not entirely straightforward because in practice we do not prepare a day s feed for one animal Rather we attempt to devise formulae by which balanced meal mixtures can be made in quantity and from which individual animals can satisfactorily be fed by adjusting daily allowances to their energy needs To be practicable for general use such formulae must be flexible enough to permit their accommodation to price and availability of feedstuffs while at the same time retaining the necessary nutritive balance and adequacy

The idea of flexible formulae *is a departure from traditional interpretation of feeding standards although in the commercial manufacture of balanced feed mixtures limited feed substitution has been common but usually on a second choice basis Particular consideration of feeds in the light of their interchangeability in rations has not*

been usual in our teaching The idea of flexible formulae is an outgrowth of the concept of nutritionally legitimate feed substitution, and hence it is not surprising that such formulae have not previously been emphasized Perhaps this omission is one reason that the feed industry has felt that college courses in feeds and feeding have failed to bridge the gap fully between fundamental nutrition and practical animal feeding—at least in the sense that such courses have given little guidance in problems of ration formulation In Canada 85% of non-roughage feedstuffs passing through domestic trade channels finds its way into commercially prepared mixtures for livestock and poultry feeding This amounted to something like 2½ million tons in 1954

In the United States the Feed Formula Industry was one of the top ten of the nation in 1954, and represented the processing of some 35 million tons of feeds This does not represent as great a proportion of the total non-roughage feeds passing through commercial grain channels as is the case in Canada chiefly because of the large tonnage of corn fed out to hogs and/or cattle in the U S on the farms where the grain was produced In Canada the counterpart of U S corn is milling wheat, the normal disposition of which is as human food Nevertheless in the U S in 1954 30% of all concentrated feed consumed by livestock came out of some manufacturer's branded bag, representing 70% of the annual feed requirements of the poultry, 30% and 18% of the non-roughage feed of dairy cattle and of beef cattle respectively, and 8% of the swine feeds

There is no doubt that ration formulation is an important part of livestock feeding Acceptance of alternate, with no implication of next best, *choices between nutritionally similar feeds in ration formulation attained full respectability in Canada with the adoption by the Quebec Provincial Feed Board in 1942 of the flexible formula as a method of presenting the Board's official ration recommendations and the sanction by the Canadian Feed Control Officials of guarantees by feed manufacturers containing such statements as "corn and/or wheat or linseed and/or soybean oilmeal" to indicate the possible use of alternate ingredients in their commercially mixed rations*

Inasmuch as no two natural feedstuffs are identical in nutrient con-

tent, together with the fact that the amounts and proportions of nutrients in any one feed may bear little relation to the needs of an animal, it follows that in practice it is impracticable, if not impossible to prepare a feed mixture, a specified quantity of which will exactly meet the feeding standard specifications for some particular animal, let alone maintain the nutrient balance when feed substitutions occur. However, there is ample evidence from practical feeding that minor excesses as well as fluctuations of nutrient intake, either from variation in daily intake of the same feed mixture or from legitimate substitutions in formulae, are inconsequential to the animal. On the other hand, alteration of the energy concentrations of the meal mixture through feed substitutions is promptly detected by the animal and usually the first limiting factor in the interchangeability of feeds within a sub-category (Chapter 11) is the extent of the useful energy yield which would result.

It is these facts that make tenable the whole scheme of preparing for a group of animals one common feed mixture. To make such a system work economically there must be flexible formulae, whether they are formally written or tacitly practiced in compounding the mixtures. The basic pattern of a feed mixture for some group of animals is fixed by the needs of the animal as detailed in the appropriate feeding standard. But in the choice of the individual feedstuffs within this pattern there can be varying degrees of latitude depending on nutritional and/or economic considerations. The latter may be general and locally uncontrollable, or they may arise from the policy and internal economy of a particular feed manufacturer. So long as the nutritional integrity of the final ration is guarded the economic considerations can be given full play without prejudice to the feed and is usually to the ultimate advantage of the purchaser.

Flexible formulae *offer a simple means of stating the appropriate basic formula pattern of indicating the legitimate choices of feedstuffs and of marking the recommended maximum and minimum limits of use of each potential selection. This section of the book deals with these matters.*

CHAPTER 15

Translation of Feeding Standards to Meal Mixture Specifications

Animal Feeding Categories

FEEDING STANDARDS state the daily needs of specified animals for some group of the recognized nutrients. Feeding practice requires that this information be translated into terms of meal mixtures and thumb rules of feeding. One of the first questions that must be settled then is—how many different meal mixtures are required to feed a herd or a flock? This is the same as asking how many feeding categories there are for each class of animal? Swine feeding standards describe requirements for six weight groupings of market pigs plus four further categories of breeding stock. Dairy cattle are described as to needs according to several groups, with separate specifications for pregnancy, and for four production categories. Beef cattle and sheep are grouped into 9 and 6 categories respectively.

Not all of these groups actually require meal mixtures of different make-up. In many cases the difference between needs of the animals is one of quantity rather than of differing concentrations of nutrients in the ration. Furthermore, economy appears to justify a reasonable latitude in the matter of nutrient allowances to individual animals since temporary minor surpluses of many nutrients that individual

animals may get as a result of the feeding of groups on the same feed mixture, do not cause obvious differences in performance

The fundamental basis for establishing feeding categories in practice is the energy-protein requirement Those animals of the same species that can be satisfactorily fed rations of the same protein level can usually be adequately nourished with identical meal mixtures if allowances are adjusted to their individual energy needs, because most of the nutrients which need to be carefully adjusted in the ration are required in proportion to the metabolizable energy The major nutrient that does not follow this rule is protein And so in applied feeding the first factor determining the number of meal mixtures needed for any class of stock is the level of protein

Swine Meal Mixture Specifications

Insofar as swine are concerned, calculations from the generalized feeding standard of Guilbert and Loosli* suggest that newly weaned pigs require a ration which, on a 90% dry matter basis, should carry 19% of total crude protein More recent work has indicated that with the use of vitamin B_{12} the protein levels of swine rations may be reduced appreciably, and the 1953 recommendation of the Swine Committee of the U S Research Council Committee on Animal Nutrition calls for 18% of crude protein for pigs of 25 lbs weight In 1954, Catron† at Iowa State recommended still lower protein levels in hog rations The data calculated or taken directly from these three sources and from the recommendations of the Quebec Provincial Feed Board are shown for various weights of market pigs in Fig 15-1

It will be evident that both the N R C, the Iowa, and the Quebec Feed Board Standards agree on 18% protein for newly weaned pigs (about 25 lbs in weight) By the time they have reached a weight of 75 lbs their protein needs have declined to between 13 and 15% depending on which of the three specific swine standards is used

* *J Animal Sci* V 10 p 22 (1951)
† *The Midwest Farm Handbook* 3rd Ed Iowa State College Press Ames Iowa

For pigs beyond 125 lbs. weight, 11 to 13% protein appears to be enough.

Neither the N.R.C. nor the Quebec Standard drops below 12% protein, and the Iowa Table levels off at 10%. However, we must remember that in practice it is desirable to include enough feeds of animal or marine origin to meet at least 10% of the total protein requirement. If the basal feed used were all corn (10% protein)

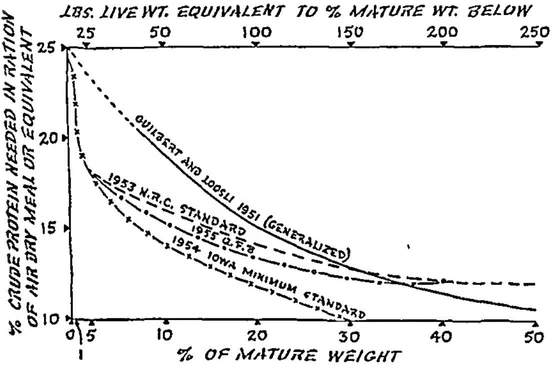


Fig. 15-1. *Trend of per cent of crude protein needed in meal rations for swine.*

and if 2% minerals were also used, the final meal mixture would then carry about 10.5% crude protein. If the basal feed carries 12% protein, as when it is comprised of course grains (barley or oats), the *minimum* protein level of the mixture in which 10% of the protein comes from animal sources becomes 12.5%. Consequently, there is little practical use in worrying about levels of protein in hog rations below 12%.

For the pigs beyond the weaning period—that is, over 75 lbs. in weight—and until they reach weights of 125 lbs., the meal mixture

evidently should carry between 12 and 18% protein The N R C Standard calls for 15% protein at this weight range, while the Quebec Stand ırd and Iowa Table calls for a minimum of 14% (if the ration does not carry antibiotic) Furthermore, practical experience with commercially prepared "hog growing rations" carrying 15% crude protein is adequate reason to consider this latter level as satisfactory for this intermediate period of market hog feeding It will carry enough margin to meet the variations in need of pigs within the weight range of 75-125 lbs

There are two further categories of pigs involved under usual swine management These include the breeding stock—the pregnant gilts and sows in one group—and lactating females in the second The N R C Standard calls for 15% protein for the gilts, and 14% for the adults, and makes no distinction between pregnancy and lactation The Quebec Feed Board recommends that pregnant and lactating sows, as well as boars, be fed a meal mixture of the same specifications as the growing pigs i e, pigs between weights of 75 and 125 pounds If the protein level of 15% is accepted for the growing pigs it will then also be adequate for the breeding stock Thus there would seem to be no practical reason to divide the swine herd into more than three ration groups, except for a special case to be noted later

The nutrient specifications for meal mixtures for the three feeding categories of swine can be derived directly from feeding standards Table 15-1 following is based on data of the feeding standard of the U S Research Council s Committee on Animal Nutrition modified by figures from the author's laboratory for bacon hogs It is expressed in terms of the several meal mixtures necessary to provide for the feeding categories of swine

In Table 15-1 the live weight groupings for the market pigs have been found in practice to be acceptable, except that the break between the starters and growers is made at 75 lbs, whereas under shortage of protein the young pigs can with little or no penalty be changed to the growing ration at 60 lbs weight (During World War II, feed manufacturers in Canada were not permitted to recommend feeding pig starters to pigs after a weight of 60 lbs) The

TABLE 15-1 *Nutrient Specifications of Meal Mixtures Suitable for Swine*

Description		Pig Starters		Pig Growers		Pig Finishers			
		Assumes pigs are nursed for 6 to 8 weeks		Also suitable for breeding stock with suitable adjustment of feed allowances		For fat pork (meal of 75-80% TDN and self-fed)		For lean bacon (meal of 64-70% TDN and self-fed)	
		25-50 lbs.	50-75 lbs.	75-100 lbs.	100-125 lbs.	125-150 lbs.	150-200 lbs.	125-150 lbs.	150-200 lbs.
Normal daily gain	lbs.	0 65	1.20	1.35	1.45	1.60	1.85	1.50	1.55
Normal daily air dry feed	lbs.	2 6	3 6	4.7	5.6	6.5	7.3	7 0	8.0
Equivalent TDN intake	lbs.	2 0	2.7	3 5	4.2	5.2	5.8	4.7	5.4
Crude protein	%	18		15		13			
Calcium		0 8		0.65		0.55			
Phosphorus		0 6		0.45		0.33			
Salt		0.5		0.5		0.5			
Carotene	mg /1000 lb.	750		750		1000			
Vitamin D	I.U. /1000 lb.	90000		90000		90000			
Thiamine	mg /1000 lb.	500		500		500			
Riboflavin	mg /1000 lb.	1200		1000		1000			
Niacin	mg /1000 lb.	8000		5000		5000			
Pyridoxine	mg 1000 lb.	600		—		—			
Pantothenic acid	mg 1000 lb.	5000		—		—			
B_{12}	mg 1000 lb.	7		5		—			

expected or normal gains per day and the normal daily feed intake under *ad libitum* feeding is shown for two weight subgroups for each of the three categories involving ration change In the case of the pig finisher we have made a distinction between animals intended to be finished rapidly and those to be fed for the leaner carcasses desired for lean bacon The ration modification in this case is in the energy (TDN) of the ration Reducing the TDN by the inclusion of bulkier feeds usually results in somewhat greater voluntary feed intake, but this is not enough to compensate fully for the lower energy level, and, consequently, the end result is less TDN intake and a less rapid gain Carcasses thus produced may be expected to carry appreciably less back fat and thus to have 5 to 10% more lean, but also due to the longer growth period (because of the slower daily gains) to show an actual increase in the surface area of the pork chop eye of lean

The feeding standard indicates that the ration for the growing pig (75-125 lbs) is also suitable for boars, for pregnant sows, and for nursing sows

Thus three rations are indicated as useful and sufficient for the five usual feeding categories of swine However, there is one further group that should be included, though it will not be a factor on many pig raising farms This extra grouping is for the pigs weaned at ages of under 3 weeks, and fed man made rations during the balance of the time that they normally would be nursed by their dams This system of pig raising sometimes referred to as the *pig hatchery* plan, promises to be increasingly important, because it makes possible more pigs per sow per year (about 3 litters in 15 months) with no greater and often a smaller feed cost per pig to an age of 8 weeks (the usually considered normal weaning age), plus the probability of a larger pig at 8 weeks, as well

Specific nutrient needs for these very young pigs are not yet known but empirically devised highly satisfactory feed mixture formulae have been published by several experiment stations and since about 1953 several such formulae have been manufactured and sold commercially The demand for this type of pig ration is reported by feed manufacturers to be steadily increasing

The formula below, devised by the author and co-workers at Macdonald College was first included in the 1953 edition of the *Feeders' Guide and Formulae for Meal Mixtures,* published by the Quebec Provincial Feed Board It has been in commercial production since

CHART 15-A *Dry Meal for Early Weaned Pigs*

This mixture self fed as a dry meal or in pellet or crumble form with water available ad libitum has been successfully used at Macdonald College for pigs weaned from their dams at 110 days after birth Litters so fed have averaged from 30 to 35 lbs per pig at 8 weeks of age

Early weaned pigs must be given heated beds with air temperature under the haver between 75 and 80° F Heated floors (radiant heating) are preferable since this keeps the bed dry as well as warm

Pigs when weaned abruptly will usually learn to eat with 24 hours without assistance Providing them with milk or gruel is not desirable since they learn to eat dry feed more quickly when no other feed is offered

Formula		Average Analysis	
370 lbs	skimmilk powder	Protein	30%
100 lbs	Ground wheat	Fat	3%
150 lbs	Ground oat groats	Fiber	2%
100 lbs	soybean oilmeal	Calcium	1 6%
100 lbs	fishmeal	Phosphorus	1.1%
50 lbs	Brewers' yeast		
100 lbs	Cane molasses	Thiamine	2 0 mg /lb
24 lbs	Bone flour*	Riboflavin	4 0 mg /lb
5 lbs	Fine salt (iodized)	Niacin	15 0 mg /lb
1 lb	Ferrous sulfate	Pantothenic acid	10 0 mg /lb
1000			

Add to each 1000 lbs. materials to supply

7 gms	antibiotic
7 mgs.	B_{12}
2 gms	Riboflavin (800,000 B S units)
2 gms	Pyridoxine
4 gms	Pantothenic acid
4,500,000 I u	Vitamin A
100,000 I u	Vitamin D

* Finely ground feeding bone meal

that date The formula and directions for its use, as they appeared in the *Feeders' Guide* are reproduced in Chart 15-A

Dairy Cow Meal Mixture Specifications

We cannot calculate the specifications of a meal mixture for dairy cow feeding directly from feeding standards, and for two reasons First, requirements are for a cow of particular size, level of lactation, and stage of pregnancy Second, the meal allowance is only a part of the complete ration However, as with hog rations, it is protein level more than consideration of any other nutrient that determines how many different mixtures will be needed to satisfy the needs of different feeding groups

Insofar as growing dairy animals are concerned, calculations (see Chart 6-A) from the latest U S Research Council Dairy Cattle Feeding Standard indicate that up to live weights equivalent to about 25% of their expected adult size, meal rations should carry not less than 18% total crude protein, and for the younger animals 20% would not be excessive From that stage of development on, meal mixtures of 16% protein are adequate under normal feeding practice

For the maintenance of adult non milking stock, meal allowances are not ordinarily needed except for heifers in calf for the first time Here feeding standards suggest a daily allowance during the last two or three months of pregnancy of 8 lbs of meal, containing 6 lbs TDN and 0 6 lbs DCP Assuming a digestibility coefficient of 80% for protein and that the TDN is 75% of the weight of the feed we can see that this meal allowance needs to carry only 10% of total crude protein Since this is less protein than is in a mixture of basal feed grains, there is no special meal mixture (as to protein) re quired for animals of this category

For the milking cow, however, the story is more complicated For the milk production itself, the proportion of TDN that should be digestible protein is about 14% However, since the feeds other than meal also fed may not exactly meet maintenance needs the meal mixture specifications will be influenced by the kind and amount of the roughage used

Perhaps the easiest way to describe the requirement is to calculate

example cases that will cover the usual situations found, and from them attempt to arrive at valid conclusions regarding the number of meal mixtures of differing protein levels needed to feed dairy cows generally.

The starting point is, of course, the feeding standard; but which standard? As discussed in Chapter 6, it seems probable that a 1,000 lb. dairy cow requires about 6.5 lbs. TDN per day for maintenance. This is approximately 20% lower than the value recommended by the U.S. Research Council Dairy Cattle Standard Committee. However, they state that their figure is above the actual needs and was decided on because too meager energy intake was the most frequent cause of poor performance. Their stated reason is a valid argument for recommending liberal allowances of a ration, but a weak one for establishing a standard. Where meal mixtures are to be made for the practical feeding of groups, the margin for error should be on the side of minimum energy requirement in order that the allowances of meal sufficient to maintain the body weight of the cow shall also contain a sufficiently high concentration of protein, minerals, etc., to meet her needs.

Consequently, in the calculations to be made in our examples, we shall use the value of 6.5 lbs. TDN as the most probable true maintenance need per day for a 1000 lb. cow.

We may take the protein level as:

$$\text{DCP lbs.} = \frac{3.4 \times 146\ (455^{.75}) \times 6.25}{454 \times 1000} = 0.65 \text{ lbs.}$$

as discussed in Chapter 7. This figure for a 1000 lb. cow is to be compared with 0.60 given by the U.S. Standard and values of 0.60—0.65 lbs. given by Morrison.

For 4% milk, all standards agree well enough for us to assume values of 0.32 and 0.045 lbs. of TDN and DCP per pound of milk, respectively.

The next step is consideration of the roughage to be fed. Here we have to make a choice of a number of possibilities. Of high quality (high energy) roughage we may take a typical TDN value of 53% and total crude protein at a minimum of 6%. Of such rough-

age average, voluntary consumption can be estimated at 2 5 lbs per 100 lb weight of cow An example of the steps in calculating the per cent of crude protein needed in the meal mixture is shown in Table 15-2

TABLE 15-2 *Example of Calculations of Protein Level Needed in Dairy Cow Meal Mixtures*

1000 lb dairy cow producing 50 lbs of 4% milk fed roughage of 53% TDN and 6% DCP	DCP lbs.	Equiv TCP lbs.	TDN lbs.	Equiv meal lbs.	% crude protein to be in meal
Requirements					
Maintenance	0 65		6.5		
50 lbs 4% milk	2 25		16 0		
Total	2 90		22.5		
In 25 lbs good roughage	1.50		13.25		
To be supplied in meal	1.40	1.75	9.25		
Pounds of meal @ (72% TDN)				12.7	
% total protein needed in meal					13.7

In the calculations of Table 15-2 we have assumed that the DCP in a meal mixture is 80% of the total protein, and that such a meal carries 72% TDN These figures are based on a typical mixture in which the basal feeds include significant amounts of barley and/or oats Use of a heavier meal, one carrying perhaps 75% TDN as might be the case where the basal feeds were largely corn, would raise the per cent of protein needed to 14 2%

Using appropriate figures for cows of 1000 and 1200 lbs live weight, for productions of 30 and 50 lbs of 4% milk, for the requirements of early and for late pregnancy, and where good hay in the one case and only fair roughage in the other is fed the per cent of total crude protein needed in meal mixtures has been calculated (as shown above) for cases (a) where adequate meal is fed to meet TDN needs fully, and (b) where this meal allowance is restricted to 75% of the total needed to meet energy needs These calculations are given in Table 15-3

TABLE 15-3 *Per Cent of Protein Needed in Milking Cow Meal Mixtures*

Weight of cow	Av daily 4% milk produced	Stage of pregnancy	Daily consumption of roughage (hay or equiv)	Lbs needed of meal 72% TDN to meet energy requirement	Lbs total protein of 80% digest needed in meal allow	Level (%) Total crude protein needed in meal mixt (a)	(b)
	(lbs)		(lbs)			(a)	(b)
1000 lbs	30	Early	25	3 9	0 62	15 9	20 0
			15	12 5	1 75	14 0	19 0
		Last 2 months	25	12 2	1.38	11 4	15 0
			15	20 8	2.50	12 0	16 0
	50	Early	25	12.7	1.75	13.7	18 5
			15	21 4	2 88	13 5	18 0
		Last 2 months	25	21 1	2 50	11 9	15 8
			15	29 8	3 62	13 3	16 3
1200 lbs	30			(2 5)		(15 1)	(22 0)
		Early	30	1.7	0 38	22 4	30 0
			18	12 0	1.72	14 4	19 0
		Last 2 months	30	8 6	1 12	13 0	17 5
			18	20 2	2 48	12 4	16 5
	50	Early	30	10 6	1 50	14 1	18 8
			18	20 8	2 88	13 8	18 5
		Last 2 months	30	18 9	2 25	11 9	16 0
			18	29 1	3 60	12 4	16 5

(a) Normal meal allowances
(b) Meal reduced 25%

It will now be in order to examine the figures in some detail It is possible by averaging together all of the protein levels that apply to the 1000 lb cow, and then all of those applying to the 1200 lb cow, to see what general effect different size of animal has on the per cent of protein required in her meal mixture This calculation will cover all of the various conditions other than size of cow that were included

in the calculations When we make our calculations we find that the average per cent of protein required in the 1000 lb cow meal mixture is about 13 5%, while that for the 1200 lb cow is 14 5% This result would lead to the conclusion that as larger cows are involved a slightly higher percentage of protein will be needed

Insofar as milk production is concerned, and making the comparison in the same way, we find that for 30 lbs of milk a meal mixture of 14 5% protein is required, and for 50 lbs of milk 13 5% protein is enough This result shows that for larger production, slightly less protein is required in the meal mixture

It is assumed that until the last two or three months of pregnancy there is no increased nutritional requirement that needs to be taken into account by the feeder However, for the last two or three months of pregnancy additional feed and nutrients must be given in order to make good the drain on the cow occasioned by the rapid growth during this period of the foetus Insofar as per cent of protein needed in the meal mixture is concerned, we find that during early pregnancy the average figure is 15 2%, but that during late pregnancy when additional feed is given the per cent of protein drops to 12 7% This drop, of course, is due to the larger meal allowance called for to meet TDN demands When we change from good hay to poor hay there is less than 1% difference in the protein required in the meal mixture to satisfy the requirement

In Table 15-3 there is one case where calculation indicates a need for a protein level of 22 4% in the meal This high level however, is due to the very small quantity of meal needed to complete the energy requirements over the TDN supplied in the roughage If as much as 2 5 lbs of meal were fed, its protein content necessary would be 15% This case is a special one and need not be considered as altering the general situation

Taking all cases into consideration, the average per cent of protein required in the meal mixture is 14% The range (deleting the case noted above) is from 15 9% in one case where a very small allowance of meal is required down to as low as 11 9% where relatively heavy feeding is involved Evidently, therefore, we can conclude that the dairy cow meal mixture need not contain over 16% of protein

under any normal conditions, and that for most of the common feeding conditions found 16% protein will be about 2% more than is actually required This conclusion agrees very well with the fact that the commercially prepared standard milking cow meal mixture sold in North America is likely to contain 16% of protein

There is, however, another situation that we must face when feeding dairy cows It is that situation where the meal allowance offered is somewhat less than would be required to complete the full energy requirement of the cow We find such situations occurring in early lactation where, because of the high production, the cow is unable to consume as much meal as would be required to fully meet her energy requirements It is probably unwise to expect a cow to consume more than 25 lbs of meal per day, when the cow needs more than that she has to get some of her energy by metabolizing body fat In other words, a part of the energy requirement is provided by the cow herself in lieu of feeding the full amount of meal that would otherwise be necessary This curtailment of the amount of meal has nothing to do with the amount of protein that is required, and consequently where meal allowances are restricted below those that would complete the full allowance for energy, the per cent of protein in the meal mixture must be raised Actually our table shows that if the meal allowance is cut by 25% there will be an increase in the average per cent of protein from 14% at the normal feeding level to over 18% in the restricted meal feeding program

And so we see why it is that under some conditions a dairy cow meal mixture carrying 18% protein has been found to give more satisfactory results than the 16%, and also why most feed manufacturers offer both a 16% and 18% milking cow ration, though many feeders are unaware of the reason

It appears, therefore, that three different meal mixtures will probably be required to adequately supply the protein requirements of the different feeding classes of the dairy herd One will carry about 20% of protein, and such a mixture would be for the calves and yearling heifers The second would carry about 18% of protein, and would be satisfactory for the two-year-old heifers and also for cases where for any reason somewhat restricted meal allowances were given to cows

in milk as compared to the full requirement In such cases one might expect that there would be some loss in body weight during the period involved because of too meager energy intake The third meal mixture, which would represent most of the usual feeding of milking cows, should carry somewhere in the neighborhood of 16% for most economical results

Other Nutrients of the Dairy Cow Meal Mixture. The concentration of other nutrients needed in these meal mixtures will also be affected by the quantities of these nutrients that the roughage will supply The number of nutrients to be considered is not large, partly because the dairy cow synthesizes via the microorganisms of her rumen all of the *Vitamin B complex* required, and she normally gets in almost any kind of forage all of the *Vitamin A* she needs Probably, also, the *Vitamin D* requirements are met through her exposure to the sun in the summer during grazing Insofar as minerals are concerned we must, of course, consider *calcium* and *phosphorus* and in many areas *cobalt, copper,* and *iodine* as well In this country *salt* will also have to be supplied, but this is done as a matter of routine, regardless of any quantities of sodium or chlorine that may be in the forage The problem of supplying cobalt, copper, and iodine is one of specific additions to the meal ration rather than in choice of roughages

And so in the end we find it necessary to consider only the calcium and phosphorus that the roughage intake will supply to the animals as compared to the quantities specified by feeding standards as required Reference to Chapter 14 indicates quite clearly that when cattle are fed under conditions requiring no meal mixture, it will usually be necessary to supplement the roughage ration with phosphorus but not with calcium On the other hand, when meal mixtures are used in dairy cattle feeding, the specifications of the mixtures with regard to calcium and phosphorus are obviously tempered by the quantities and kinds of roughage also consumed In order to get an idea of what supplementation is required for meal mixtures intended to be fed to cows in milk, we can use the same general scheme we used in determining the protein levels

Examination of the feeding standards indicates that differences in

weight between adult cows are relatively insignificant in terms of the calcium and phosphorus requirement as compared to changes in the quantities of milk produced or changes in the stage of lactation The changes in the amount and kind of roughage also have a marked effect on the quantities of Ca and P that must eventually be provided in the meal mixture

In estimating the probable quantities of calcium and phosphorus that would be furnished by the roughage allowance, we used a figure that was 50% of what would be supplied by *average* roughage of the two categories involved, and, because of the general tendency of feeders to restrict dairy cows in their meal allocations, we have based our calculations on a feeding program in which only three-quarters of the full allowance of meal was actually fed We believe that by making these two modifications the calculations give the quantities of bone meal that would be required under the most adverse conditions likely to be met with in actual feeding practice The assumption that in any given case the roughage may furnish only half as much, either of calcium or phosphorus, as would be found in average samples is predicated on the fact that soil phosphorus deficiency is widespread in farming areas, and that under such conditions the phosphorus content of the forage is appreciably lower than average Similarly, there are many soils that have a high lime requirement, and such land tends to produce forage low in calcium

The figures obtained from the above-mentioned calculations show that need for supplementary sources of calcium and of phosphorus varies from none at all, where feeding of average roughage plus enough meal to fully meet energy requirements is followed, to amounts equivalent to including bone meal to the extent of 3% in the meal allowance where calcium- and phosphorus-poor roughage must be fed, and/or where meager grain allowances are offered The average requirement of bone meal per 1000 lbs of meal mixture for all cases calling for such additions was 18 lbs to meet calcium and 19 lbs to meet phosphorus deficits We realize that individual cows for varying periods of time during a lactation are likely to be in one or another of all the different situations covered by the calculations, and that through the function of the bone trabeculae fluctuations in

intake of calcium and phosphorus above and below the exact requirement are not critical We believe that the inclusion of supplements to provide 2000 gms of calcium plus 920 gms of phosphorus per 1000 lbs of meal mixture should be routine practice Twenty pounds of feeding bone meal in 1000 lbs of an 18% protein meal mixture will meet these levels (Bone meal is used merely as a typical Ca–P supplement It implies no special preference for this source of these nutrients)

We should also mention the question of common salt Standard dairy cattle feeding for many years has called for the inclusion of 1% of common salt in the meal ration This amount meets average conditions In general, where normal amounts of meal are being fed, cattle show no requirement for salt beyond the 1% included in their meal allowances (Cows that are receiving no meal should have access to a mineral mixture in order to provide salt and phosphorus)

Wherever there is evidence of iodine deficiency, as indicated by the birth of goitrous calves, the meal should be fortified with iodine, which can be supplied most simply by using iodized salt One fifth of an ounce of potassium iodide per 100 lbs of salt is probably adequate for this purpose There are also geographic areas where cobalt deficiency is known to exist In such areas the salt might also be cobaltized, using approximately 2 5 times as much cobalt sulfate per 100 lbs of salt as is recommended for iodine (The problem of copper and/or molybdenum is discussed in Chapter 14)

Beef Cattle Meal Mixture Specifications

Meal mixtures for the several classes of beef cattle are similar in principle to those for dairy cattle There is, however, a different emphasis, growth and fattening of steers and heifers become the major interest rather than lactation insofar as concentrate feeding is concerned This is reflected in the N R C Feeding Standard where feeding categories are set out for 10 separate groups of beef animals These groups frequently differ more in management and in feeding practice than in the nature of the feed combination involved

Roughage plays a large part in the feeding program, either as for-

age to be grazed or as a harvested crop. Indeed, for any beef stock over one year old that is not on a fattening program, roughage is likely to furnish the entire energy of the ration.

A very general picture of the feeding groups and their requirements for feed is shown in Table 15-4.

If we accept the N.R.C. Feeding Standard and make calculations on the basis of forage of 6% D.C.P., we find that four meal mixtures are recognized insofar as differing protein levels are concerned (assuming that the use of a 14% instead of a 13% mix is as satisfactory for the growing and breeding bulls as it is for the growing heifers). Thus, the 500 lb. calves being finished as baby beef or as short yearlings should have a meal mixture carrying about 18% total crude protein: The animals of this category, when they have reached 800 lbs., can use a 14% protein mix. Growing heifers of 400 to 500 lbs. and growing bulls of 800 lbs. will also need the 14% protein meal ration. It will be well to have about 12% protein in the ration for the lighter yearlings when they start the feeding period. Finally, a meal carrying 7-9% protein will meet the needs of all other groups to which feed other than roughage is to be given. This level of protein will be supplied by unsupplemented basal feeds and, consequently, is not a problem in meal mixture or protein supplement formulation.

It may be well to point out that *concentrate* and *meal* mixtures as here used are synonymous and refer to the total non-roughage feed combinations. For example, shelled corn, a protein supplement, and a mineral supplement may all be made available to the stock free choice. If 10 lbs. of corn plus 1.5 lbs. of a 40% protein mineral supplement are eaten, it is the equivalent of a *meal* mixture of 14% protein.

The calculations of Table 15-4 were based on roughage carrying 6% of D.C.P., which means a good quality product that probably contains 50% legumes. If roughage of a lower protein level is used the protein necessarily derived from the meal will increase. However, lower protein roughage often also means lower TDN in the roughage and probably a tendency for reduced roughage consumption. This means more grain or meal must be fed to meet the energy

'calf' period When we recognize this difference in terminology the apparent discrepancy in protein recommendations largely disappears

The more fundamental consideration arises from the difference in the objectives and hence in the feeding management of the beef vs the dairy herds Other than for the young calves and for animals during final stages of finishing for market, the ration for all classes of beef animals is essentially roughage Concentrate feeding in a commercial enterprise is always at a minimum consistent with health Adult animals are at maintenance (or below) for most of the year and are bred at a time when the extra demands for reproduction and lactation coincide with the occurrence of forage at its most abundant and nutritious stage

When concentrate feeding becomes necessary it is usually because relative to its useful energy the content of the forage available is inadequate in protein and Vitamin A Occasionally there may also be a phosphorus shortage, especially if Prairie hay or straws are to be the principal forage Table 15-5 illustrates the general problem

We can see from this table that for those classes of beef animals that are normally fed a ration of 50% TDN (see N R C Standard) the so called "good' roughages ordinarily form an adequate ration Of the "poorer quality" roughages there are some whose energy value (TDN) is still essentially the same as that of the good quality feeds However their protein may be inadequate and they may also be short of phosphorus and carotene Hence when we depend on these roughages a protein and perhaps a mineral vitamin supplement must be used for adequate nutrition

We should point out that forages whose TDN is below 50% will require extra energy from a grain allowance, and since any grain used will also provide protein there may be no need for a high protein supplement as well Going back to the N R C Standard we find given for mature cows of 1100 lbs , a requirement of 18 lbs total feed carrying 4 5% D C P and 50% TDN If a forage carrying only 2 2% D C P and 40% TDN were used, such as fully matured Timothy, then grain would need to be fed to supplement the shortage of digestible energy If 18 lbs of total feed is still to be fed, then we

TABLE 15-5 *The Approximate Average Protein, Energy, Phosphorus, and Carotene Content of Some Common Beef Cattle Roughages*

Forage	DCP	TDN	Phos	Carotene	Supplement*
Requ rement	4 5%	50%	19%	4 mg /lb	Required
Alfalfa	10	50	24	11	none
Brome grass	5	49	28		none
Clover	7	52	19	9	none
Kafir fodder	4 5	54	18	2	carotene
Lespedeza	6	48	18		none
Mix grass and legume	4.5	50	18		none
Oat hay	5	47	19		none
Soybean hay	10	49	24		none
Sudon grass	4 5	49	26		none
Corn stover	2 1	52	05		Protein Phos
Grass hay	3 5	52	21		Prote n
Lespedeza, mature	3 6	40	15		Adequate in proportion to TDN
Prairie hay, good	2 1	50	18	9	Protein
Prairie hay, mature	0 6	47	09	1	Prot Phos, Carotene
Straws	03 1 3	45	10		Prot Phos, Carotene
Timothy, all analyses	3 0	50	.20	3	Prote n, Carotene

* Based on all feed ng groups whose total ration is shown in N R C Standard as 50% TDN

would have to use 11 lbs of the roughage plus about 7 lbs of grain This combination would also meet the protein needs if the grain were corn, and would provide a slight excess if barley, oats, or wheat were used as the grain ff, however, the cows were still to eat 18 lbs of the 40% TDN forage, it would require 2 2 lbs of grain in addition to meet the full energy needs This amount of corn grain would not supply but about 15 lbs D C P, leaving almost a third of a pound to be supplied by some high protein supplement

The solution therefore might be a mixture of 1 2 lbs corn plus 1 0 of soybean oilmeal or cottonseed meal, which would meet quite

TABLE 15-4 *Feeding Categories in the Beef Enterprise and Some Typical Feed Needs**

Feed ng Group	Av wt of animal lbs	Total a r dry feed per day lbs	Concentrate feed lbs	Roughage feed a r dry lbs	D C P needed da ly lbs	D C P n roughage of 6% D C P lbs	Prote n needed n meal O C P lbs	Prote n needed n meal T C P lbs	Total C P needed n meal %
Grow ng he fers	400	12	3 8	8 2	90	49	41	50	14
	600	16	2 0	14 0	90	84	06	08	4
Breed ng bulls	800	17	10 2	6 8	1 40	40	1 00	1 25	13
	1400	24	7 6	16 4	1 40	98	42	53	7
W nter ng stock									
calves	500	13	2 0	11 0	80	66	14	18	9
yearl ngs	700	17	0	17 0	80	1 00	—	—	—
pregnant he fers	800	20	0	20 0	90	1 20	—	—	—
mature cows	1100	18	0	18 0	80	1 20	—	—	—
F n sh ng stock									
calves	500	14	4 5	9 5	1 20	57	63	80	18
	800	20	5 6	13 5	1 50	80	70	90	14
yearl ngs	600	18	10 8	7 2	1 30	44	86	1 10	11
	1000	26	15 6	10 4	1 70	62	1 10	1 38	8
2 yr olds	800	24	11 5	12 5	1 50	75	75	94	8
	1200	29	14 0	15 0	1 80	90	90	1 10	8

* Arranged from Tables I and II of the N R C. Nut ent Allowances for Beef Cattle 1950 revis on.

needs. The end result is that the per cent of protein in the meal does not usually increase in direct inverse ratio with the decline in the per cent of protein in the roughage. When all factors are considered, the protein levels of the concentrate feed that will adequately meet nutritional needs in the beef herd when fed good roughage, appear to be:

Calves at start of feeding for baby beef	18%	total crude protein
Calves fed for normal growth	14%	
Yearlings for fattening	12%	
2-yr.-olds for fattening	8%	
Other classes	8%	

It will be interesting to compare these with the protein levels discussed as needed in the rations of dairy animals. For the young dairy calves, a meal mixture of 20% protein was found satisfactory for average conditions. Beef calves (above) are found to need only 14% protein in the meal. This difference is, in part, one of terminology. Beef calves are not fed man-made rations much before they have attained 30% of their mature weight, and are nearly six months of age. They are still calves to the beef cattle feeder, however. On the other hand, the dairy calf is weaned at one month of age at a weight representing only 10% or less of its adult size. The feeding for the next four months is one of replacing with a meal mixture the milk the beef calf gets during this period. Such meal mixtures must carry more protein than is needed during the 6-12 month age period. The situation is explained by a paragraph from the *Quebec Provincial Feeders Guide*, which states:

> It is frequently assumed by feeders that once the calf reaches an age of 6 months and is ready to go out on regular herd rations, that little attention to feeding is needed until well along in pregnancy. Thus many heifers after the calf stage fail to grow and develop as fully as they should.

From this statement we can see that the calf stage in the dairy herd unofficially ends at about 6 months of age. The feeding during the 6-12 month age period of the dairy animal is comparable in protein needs to that commonly referred to by the beef feeder as the

nicely both the protein and energy demand Such a mixture would carry a total crude protein level of about 25%, and would be referred to in the feed trade as a mixed protein supplement

Obviously there are innumerable combinations of forages, each of which yields a characteristic quantity of nutrients and energy When matched against the need of some feeding groups of animals, we find that we may prefer in individual situations supplementary feeds, ranging all the way from simple basal feeds of 9-12% protein (or even a single basal feed) to straight high protein supplements such as cottonseed meal furnishing 40 45% protein (with combinations giving all intermediate protein levels)

There is no fixed pattern of "balanced rations" for beef cattle for another reason Most of the cases that require protein supplements to the roughage need relatively little extra energy Consequently, these cases are met by the use of one high protein feed or a mixture of several The grain finishing of steers is likely to be done on farms where the basal grain, such as corn or barley, is home produced Feeders who raise their own basal feed are, therefore, interested in the formulation of protein or protein-mineral supplements The nature of the basal feed is for them a constant All of their final ready-to feed rations will be combinations of their own grain (corn, barley, etc) with varying proportions of protein, mineral, and vitamin supplements, according to the needs of the different feeding categories, which may require different rations

Thus it appears that in practice the problem of meal mixtures for the beef herd is one of formulating

1) protein
2) protein-mineral
3) mineral

supplements, each with and without vitamin sources Because one group of feeders are likely to employ corn or sorghum grain as the basal feed while others may use coarse grains (barley, oats) or wheat, the basic differences in protein and in carotene between the two types will require due consideration in the formulations And for those who use no grain the likely specific mineral of the "poor forage must be taken into account

In Chapter 16, flexible formulae for such supplements are given, together with charts for their use.

SUGGESTED READING

A series of individual pamphlets published by The Committee on Animal Nutrition, U.S. National Research Council, 2101 Constitution Ave., Washington 25, D.C.
Nutrient Requirements of Domestic Animals
Poultry (1950).
Swine (1953).
Dairy Cattle (1955).
Beef Cattle (1950).
Sheep (1949).
Horses (1949).

Guilbert, H. R., and Loosli, J. K., "Comparative Nutrition of Farm Animals," *J. Animal Sci.*, V. 10, No. 1, p. 22.

CHAPTER 16

The Preparation of Flexible Formulae for Meal Mixtures

RATION FORMULATION involves four distinct steps The first is establishing the protein level of the meal mixture, and this is done with the help of feeding standards The second is determination of the proportions of the three main feed categories necessary to obtain the protein level wanted The third is the specification of the feeds to be used in each category involed, together with a statement of the limits of substitution permissible within categories Finally, the mixture must be checked against the appropriate feeding standard for adequacy of nutrients other than protein, and amendments specified where necessary

It is as ingredients of meal mixtures that feeds other than roughages are put to work However, there is no one best mixture This is self evident from the fact that the different feeding stuffs contain much the same kinds of nutrients though often in widely different proportions and amounts Some feeds are more nearly alike in proportions of nutrients than others and are thus practical substitutes for each other Similar feeds may be grouped in a meal mixture formula according to the principal nutrient or nutrient combination they furnish in the final ration In a working formula these groups may be

1 Basal feeds
2 Protein supplements,

   a. vegetable origin,
   b. animal origin.
3. Mineral supplements,
   a. major mineral elements,
   b. trace elements.
4. Vitamin supplements.

Because the average protein content of the common feeds of the basal group does not deviate widely from 12%, and because the quantities in most animal meal rations of vitamin and mineral supplements is small, the proportions of these four feed groups are relatively fixed in the final mixture of a specific protein level. Within the categories, however, considerable latitude in the selection of the individual feedstuffs is possible without appreciably altering the feeding values of the combinations. Thus, it becomes possible to prepare what might be called *pattern mixtures* for the various feeding categories of different classes of livestock. An example of such generalized formulae, shown in Table 16-1, was taken from the 1954 Quebec Feed Board bulletin, *Feeders Guide and Farmulae far Meal Mixtures.*

In the absence of more detailed specifications, such general guides are enough to permit one familiar with feeding stuffs and with feeding practice to formulate working combinations for balanced meal mixtures.

It is preferable, however, to carry the pattern mixture idea further to the preparation of a flexible formula designed to meet the specifications of adequate diets for described groups of animals. Our purpose in this chapter is to show how this is done.

The Pattern Meal Mixture

The step by step development of a pattern meal mixture for growing swine will serve as an example of the procedure. We note from Table 16-1 that a meal mixture suitable for growing market pigs should carry 15% of total crude protein. We might also conclude from the innumerable formulae that have been proposed by experi-

TABLE 16-1 *Generalized Formulae for Meal Mixtures for Farm Livestock and Poultry*[5]

Class of feed	CATTLE[1]			HOGS			SHEEP		CHICKENS[5]			TURKEYS		
	Cows in Milk		Others except ing calves under 6 months	Early[3] weaned pigs to 60 lbs	Sows[2] and market pigs to 100 lbs	All[6] others	Nursing ewes	Lambs	Chicks[3]	Growing birds	Layers and breeders	Poults	Growing birds	Fattening birds
	Fed legume hay	Fed non legume hay												
Basal feeds Cereal grains and mill feeds	82	72	82	75	85	93	82	62	74	72	72	60	66	70
Protein Suppl Vegetable	15	25	15	15	9	4	15	25	8	14	14	15	17	16
Animal	—	—	—	5	3	1	—	—	3	6	6	5	7	6
Minerals	3	3	3	5	3	2	3	3	3	2	2	3	3	2
Vitamins[4]	—	—	—	—	—	—	—	—	12	6	6	17	7	6

[1] Fattening rations should omit bran and shorts, and in others these feeds should be limited to 25% of the mixture.
[2] Not over 50% oats for sows or 30% for young pigs
[3] Not over 50% corn or wheat May contain 20% bran for production of lean bacon
[4] Vitamin supplements as alfalfa, yeast, wheat germ, fish oil, etc
[5] In the case of poultry the scratch feed is considered a part of the formulae given
[6] Mill feeds not to exceed 10%

In this table feedstuffs have been grouped into four main classes: Viz: (1) the Basal Feeds which are represented by the farm grains and mill feeds, chiefly bran and shorts; (2) Protein Supplements, including subgroups of vegetable and animal sources; (3) Minerals, and (4) Vitamins. The livestock has been grouped in accordance with similarity of ration requirements Thus, cows in milk will need two kinds of mixtures depending on the kind of roughage being fed Fattening cattle may use the same feed as cows on legume hay, or, if desired, may be fed a mixture in which the mill feeds are replaced by basal feeds.

ment stations, extension services of colleges, and government departments of agriculture, or have found their way into textbooks on hog feeding, that such a meal mixture *could* be made up principally of:

Farm grown grains
Linseed oilmeal
Meat meal
Limestone
Salt

These same sources of information will also lead to the tentative conclusion that 1% limestone or comparable source of calcium is needed. Salt is universally added as 0.5% of the ration. We could also calculate from feeding standards as follows:

Nutrient	Requirement 100 lb. pig per day	Normally in pig feeds	Needed in minerals	Equivalent in mineral carriers	Needed in 100 lb. feed mix*
Ca	15.6 gms.	7.8	8 gms.	22 gms. (limestone)	400 gms. ≎ 1%
P	10.8 gms.	10.7	0	—	—
Salt	20.0 gms.	0	12 gms.	12 gms. salt	240 gms. ≎ .5%

With respect to the linseed oilmeal-meat meal proportions we may make use of a common thumb rule that at least 10% of the protein should come from an animal or marine source. Thus in a 1000 lb. batch of a 15% protein meal mix, 15 lbs. of protein must be from meat meal, and this will call for 30 lbs. of this feed.

With this information we can determine the quantities of each of the feeds to make a 1000 lb. batch.

	Feed	Protein
Total wanted	1000 lbs.	150 lbs.
Meat meal	30	15
Limestone	10	0
Salt	5	0
Other feeds (by difference)	955	135

$$\text{The per cent of protein to be in other feeds} = \frac{135 \times 100}{955} = 14\%$$

* Based on 5.6 lbs. feed daily.

The proportions of the linseed oilmeal and the farm grains (i e , other feeds) needed can be easily calculated using the *cream blenders* scheme We need only to know that the oilmeal carries 35% protein and we shall figure in the example that the farm grains carry 12% We have already determined that the mix must be 14% protein

Farm grains	12%	21	parts = 91%
	14%		
Oilmeal	35%	2	parts = 9%
		23 00	parts

Thus we require of oilmeal, 955 × 9% = 87 lbs , and of farm grains 955 × 91% (or 955 − 87) = 868 lbs

Our final 15% protein pattern mixture then becomes

Farm grains	868
Linseed oilmeal	87
Meat meal	30
Limestone	10
Salt	5
Total	1000 lbs

This is not yet the completed ration It may require amendments to augment some of its minerals and vitamins, and we may wish to add an antibiotic It does however, form a pattern that establishes the proportions of key feeds needed to fix its protein level From what we said in Chapter 11, it is evident that the particular feeds shown in this formula are merely key feeds, representing in each case feedstuffs of a particular category of the feed classification Thus, linseed oilmeal could as well be soybean oilmeal, or peanut oilmeal, or a mixture of two or more of the feeds in this category Indeed, we might expand our simple formula to list some possible substitutes for each of the feeds of the simple formula (see Table 16-2)

TABLE 16-2 *Skeleton Formula for 15% Protein Swine Ration**

Main groups	Subgroups	Feeds	Recommended amounts
Basal feeds 868 lbs (Av 12% protein)		Barley	868
		Corn	
		Oats	
		Wheat	
Protein Supplements 117 lbs (Av 40% protein)	30 40% protein plant origin (87 lbs)	Linseed	87
		Soybean	
		Peanut	
		Coconut	
	35 70% protein animal origin 30 lbs (total to provide minimum 15 lbs protein)	Meat meal	30
		Fish meal	
		Milk powder	
		Tankage	
Mineral Supplement 15 lbs		Bone meal	
		Dicalcium phosphate	
		Ground limestone	10
		Salt	5
Vitamin Antibiotic supplements		Vit A (i u)	800 000**
		Vit D (i u)	90 000†
		B_{12} (mgs)	5
		Antibiotic (gms)	5

* This is merely an example and is not a complete ration (see Chapter 19 for hog ration formulae)

** About 0 25 gms dry A

† About 2 mgs dry D

Making the Pattern into a Flexible Formula

When expanded as shown we have the start of a flexible formula that can serve as a guide to innumerable combinations of feedstuffs, any of which will result in a 15% protein mixture However, because of individual differences in feeds of the same category, care must be

taken in the substitutes or alternative choices made Often the question is not whether to use this or that feed, but how much of each By making partial substitution we may be able to take advantage of desirable feeding properties or attractive prices and at the same time avoid undesirable consequences of an unrestricted use of some product

We can incorporate into our flexible formula a guide to cover these points We have to add a column setting the maximum limit of use for each feed listed, and a further column in which a figure may be set to insure the minimum use of some feed

The figures in these two added columns obviously should be based on sound evidence Properly set they are an insurance against inadvisable combinations that might be put together by one not fully aware of the peculiarities of certain feeds The "minimum" figures are also of use in cases where because of "protective" nutritional properties or because of price or availability we want to be certain we have not overlooked a product

Such an oversight might well occur in commercial feed manufacture where a by-product of a particular company is to be sold largely through the "balanced rations" they make Thus a milling company that prepares table hominy might depend on including corn by-products in their balanced rations for livestock as a way of disposing of such feeds The figures set for the minimum in this case might be based on anticipated supplies, other markets, company policy, etc , rather than entirely on nutritional considerations In another case there might be a wish to ensure a low energy ration for bacon production by the inclusion of a bulky feed such as oats or bran

The maximum and minimum limit figures are obviously subject to revision from time to time, and may also be widely different in different geographic areas They can be, and very likely will be tempered by prejudices and beliefs of the author of the formula Unless these are incompatible with nutritional considerations they are not fundamentally serious

Sub-formulae

One useful feature of this type of formula (a consequence of the grouping of feeds used) is that it can be broken down into several sub-formulae For example, we can derive recipes for a protein supplement and another for a mineral or mineral-vitamin supplement

The *protein supplement* would be

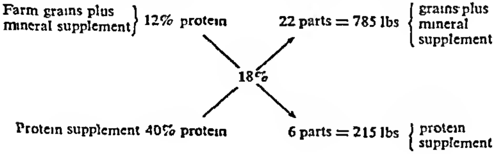
Feeds	Original amounts (110 lbs)	1000 lb basis
Linseed oilmeal	87	740
Meat meal	30	260

and the *mineral-vitamin* combination

Feeds		Original amounts (15+ lbs)	100 lb basis
Limestone	lbs	10	67
Salt	lbs	5	33
Vitamin A	(i u)	800,000	5,000,000
Vitamin D	(i u)	90,000	600,000
Vitamin B_{12}	(mgs)	5	33
Antibiotic	(gms)	5	33

Using the Supplement Formulae

To use these supplements to prepare mixtures of different protein levels, we can easily calculate the quantities of protein supplement we need per 1000 lb batch For an 18% mixture we would figure



Since we are to use 15 lbs minerals in our 1000 lb batch (see Table 16-2), our proportions become

Farm grains	770 lbs
Protein supplement	215 lbs
Mineral supplement	15 lbs
Total	1000 lbs

Note that the protein and the mineral supplements are treated separately The latter is needed in proportion to the total mixture rather than to the protein supplement The quantity of mineral supplement is so small that it can be neglected insofar as any practical effect on protein level is concerned Hence in calculating proportionate parts we take the basal feeds plus minerals as 12% protein *

Here we see the origin of the mixed supplement, usually called in the feed trade a *concentrate* Such combinations are of interest to the feeder who wishes to use his home-grown grain to prepare the several rations needed in the feeding of his animals Even though some ingredient of the concentrate may not be needed for some one ration, its presence is not likely to be harmful Such concentrates can be made "flexible" merely by listing possible substitutes where they exist, and setting minimum and maximum limits for their use (see Chapter 17)

Precautions

We must remember that flexible formulae are guides, and from the latitude they permit in feed selection are subject to abuse Improper substitution can result in undesirable modifications of the protein

* *In this example we have taken the farm grains as 12%* crude protein This of course will be too high if the basal feeds to be used include a large proportion of corn or milo The principle of the flexible formulae does not depend on any particular protein level of basal feeds or of protein supplements If in a corn area this feed is to make up 100% of the farm grains the only change from the example given above will be in the proportion of basal feeds *to protein supplements* The steps in deriving the formulae are in every respect identical to those used in the example Incidentally the average protein of a mixture of equal parts of barley, oats, corn, and wheat is almost exactly 12%

levels of the final mix, although this modification will be minimized as we increase the number of feeds we use. Also, it may be possible to make mixtures of unsatisfactory palatability or of too heavy or too bulky a nature. These limitations merely emphasize the fact that in addition to whatever formulation guides may be available, some knowledge of feeds and some nutritional judgment are necessary qualifications of anyone who is to successfully compound nutritionally adequate livestock rations.

SUGGESTED READING

Crampton, E. W., "A Method for Determining the Composition of a Meal Mixture Suitable for a Given Purpose," *Sci. Agr.*, V. 8, p. 235 (1927).

Feeders Guide and Formulae for Meal Mixtures, Quebec Provincial Feed Board, E. W. Crampton, Secretary; Prov. Dept. of Agr., Quebec, Can. (1955).

CHAPTER 17

The Preparation of Mixed Mineral Supplements

FROM THE DISCUSSION in Chapter 16 it is evident that we shall require a consideration of mineral supplements before we can formulate a balanced ration for any class of farm animal It may be well, therefore, to deal with mixed mineral supplements before going further with the preparation of complete meal rations

Flexible Formula Mineral Supplements

When grain feeding is the normal practice as with hogs and with most categories of dairy cattle, the problem of supplying any necessary mineral supplement is simply solved But beef cattle and some classes of dairy cattle, on the other hand, frequently receive no concentrate feeds The forage on which they subsist may be deficient in minerals Consequently, some special consideration of the makeup of mixed mineral supplements may be in order at this point

In one sense the mineral supplement is a comparatively simple combination of materials, each often supplying fixed quantities of one or more needed elements Thus, while bone meals may vary slightly from sample to sample, they are, relative to plant seeds or the forages, feedstuffs carrying 23% calcium and 11% phosphorus They deviate from these values only slightly This small deviation is partly due to the fact that dry, fat-free bone varies in makeup chiefly by the sub-

stitution in the $CaCO_3$ of such radicals as F, OH, Mn, etc., for all or part of the $[CO_3]$. The $[Ca_3(PO_4)_2]$ part of the structure is for all practical purposes, a constant.

Furthermore, bone meal, as purchased, is a composite from thousands of animals, and so any variation between animals is averaged out in the commercial product.

There is more variation in the makeup of some of the phosphorus sources that have their origin in rock phosphate or in the softer deposits of high phosphorus-containing bird skeletons, such as are found in the Curaco Islands. Some of the variation is natural and some is a result of processing, sucb as in the manufacture of phosphatic fertilizers or, incidentally in the removal of fluorine.

Mineral Supplements for Cattle or Sheep. Under practical cattle or sheep feeding conditions when normal amounts of roughage are fed, no intentional inclusion in a mineral supplement of sources of calcium are justified. The more common sources of feeding phosphorus are combinations that include as much calcium as phosphorus.

In more or less localized areas there may be deficiencies in forage which make it desirable to include in the mineral mixture copper, cobalt, iodine, and/or manganese. Because they are needed in such small amounts relative to calcium, phosphorus, or common salt, they are sometimes referred to as trace minerals (see Chapter 8). Their function appears to be specific, but except for iodine, their roles have not been fully elucidated. It is probable, however, that a part of the function of at least some of them is related to the nourishment of the microflora of the rumen and/or caecum of the host animal; or that their use to the animal is mediated by the microflora. The details are less important here than is the fact that some low-grade forages are readily eaten and yield available energy about equal to that of the so-called good forages if supplemented by Vitamin A, *a small quantity of minerals* and by a source of nitrogen, which may be protein or a product such as urea. Corn cobs, for example, can furnish all of the roughage for fattening steers if Vitamin A plus a mineral mixture that is adequate qualitatively and quantitatively is fed, and, of course, appropriate allowances of grain and protein

supplement are also fed In experiments at the Ralston Purina Company Research Farm, cobs replaced pound for pound all of the hay, and since the amounts of other feeds were comparable, and equal gains were made by the steers (about 2 5 lbs per day), it follows that the cobs furnished available energy to the animals equal to that from like weights of alfalfa hay *

Information as to the optimum composition of a perfect mineral supplement is lacking We do know enough already to prepare combinations that will give acceptable results, and we have no reason to think that excesses of specific minerals, which undoubtedly exist in many of the rations giving excellent results by present standards, are nutritionally harmful This thinking perhaps leads us to the use of "shotgun mixtures," which in the past have so often been decried by the animal husbandman However, there are differences between shotgun mixtures, and perhaps the ones that are the result of educated guesses based on sound though limited experimental evidence can with advantage now be removed from the category of quack remedies In any case this author believes it to be amply proven that because roughages are so highly variable in nutrient makeup from sample to sample, that fortification with complex mineral mixtures may more often than not be sound feeding practice

Flexible formulae for mineral mixtures that permit the local selection of carriers available are easily prepared The chief item of choice will be the phosphorus carrier The other variables are largely matters of inclusion or exclusion

Supplementary Phosphorus Levels for Beef Cattle. Some idea of the supplementary phosphorus needs of beef animals, for example, can be had from feeding standards Certain assumptions must be made concerning the kind and amounts of forage and meal (if any) that are fed

If we assume that the average phosphorus content of poor roughage is 0 1% and that the animals of the several feeding groups are to receive rations of hay or hay plus grain to meet energy needs set out in the feeding standard, we can prepare a table showing the sup-

* *J Agr Sci* V 14 p 797 (1955)

plementary phosphorus that would be needed to meet probable shortages (see Table 17-1).

TABLE 17-1 *Desirable Supplementary Phosphorus Levels for Beef Cattle*

Category	Daily P requirement	Phosphorus furnished daily in		Additional P needed per day
		Meal	Poor hay	
	gms.	gms.	gms.	gms.
Growing heifers	15	8	4	3
Young bulls	18	12	8	—
Wintering				
calves	12	3	6	3
yearlings	12	—	9	3
heifers and cows	16	—	10	6
Fattening				
calves	16	9	5	2
yearlings	20	15	4	1
2 yr. olds	20	15	6	—

From these calculations one could draw the conclusion that beef animals fed poor roughage (0.1% P) might need up to 3 gms. of phosphorus per day in addition to that obtained in their normal feeds. It might be desirable to double this amount for pregnant heifers.

The ingredients of the mineral mixture, other than the phosphorus source, should include salt. Mineral mixtures without salt are not consumed uniformly well when offered as licks.

Salt–Phosphorus Ratio. The principal ingredients contributing to the weight of the mineral mixture are the calcium-phosphorus carrier and common salt. The proportions of these two are of some importance in the mixture if it is to be self-fed by itself. The ingredient which determines the quantity that will be eaten voluntarily is the salt. Hence if the salt forms too large a portion, the consumption of the other ingredients will be inadequate.

Experiments indicate that voluntary salt intake by cattle on the

range is from 1 to 2 5 lbs per month Since we are concerned with adequate consumption of the mineral mixture, we are justified in figuring on the one pound per month salt intake, equivalent to 15 gms per day If, now, we use the figure of 3 gms of phosphorus as the probable maximum daily requirement, then we shall need to provide something like 30 gms of a phosphorus carrier such as bone meal From these two figures we arrive at the proportion of 1 salt plus 2 of bone meal as the basic part of the mineral mixture, i e , salt is 33% by weight of the mineral mix This ratio obviously will change if we use a more concentrate source of phosphorus, but since several products carrying 12% or less of phosphorus are popular, the basic figure of 33% salt in the mineral mix is a practical working figure It also makes inclusion of any minor elements at the expense of the phosphorus carrier quite safe, and at the same time makes it possible to include the trace minerals in proportion to the salt, since the latter remains a constant

There are also a few products carrying 20–24% of phosphorus now available for stock feeding If these are used, calculations will show that to supply the phosphorus needed with the same (15 gms) salt intake, the proportions of salt to phosphorus carrier will be about 1 1 To use the 1 2 ratio would be wasteful of phosphorus, though probably otherwise harmless Consequently, it might be desirable to prepare two mineral formulae—one to be used where the source of phosphorus was one or more of those products analyzing from 10 to 14%, and another for those of 20–24% phosphorus

Proportions of Other Elements. Insofar as the other elements are concerned the feed manufacturer will probably wish to include iodine, cobalt, iron, copper, and perhaps manganese, and this inclusion is justified on the grounds that the mix may be fed in many different areas, in some of which there may be need for some or all of these ingredients For local use any one or more of these trace minerals can be omitted without changing the mixing formula appreciably because of the small proportions in which they are used *The more important consideration is the quantity that will be effective if they are to be included* The use of too meager amounts results

in an ineffective supplement, while excesses are uneconomical, and nutritionally unnecessary.

TABLE 17-2 *Flexible Formulae for Mineral Supplements for Cattle and Sheep Feeding (Figures are pounds unless otherwise noted)*

Source of mineral elements		% of Phosphorus in carrier	No. I Using lower phosphorus carriers	No. II Using higher phosphorus carriers	Salt licks
Mino-calcium phosphate		24		50*	0
Di-calcium phosphate		20			
Bone meal					
steamed		14			
char		13	67*		0
raw		10			
Rock phosphate		9-13			
Salt (NaCl)			33	50	100*
Trace elements (added at expense of P carrier)					
copper sulfate	gms.		150	225	1.0
potassium iodide	gms.		2	2.8	.2 oz.
cobalt chloride	gms.		5	8	.5 oz.
manganese sulfate	gms.		140	210	1.0
Amounts of mixture to be consumed daily per adult to supply salt needs			Beef 1.5 oz. Dairy 3.0 oz.	1.0 oz.	.5 oz.

* Minus total of trace elements used.

Table 17-2 gives two pattern flexible formulae for mineral mixtures for cattle and sheep in which the quantities of the trace elements are adjusted to the salt level in accordance with experimental evidence and feeding standard recommendations. A salt lick is also included. These mixtures are flexible as to source of phosphorus and also in the sense that the trace elements may be omitted; but inflex-

ible as to salt and the proportions of trace elements to salt where they are included When consumed in amounts to result in a daily intake of 15 gms of salt the intake of the other elements should be adequate There is no evidence that larger consumption by individual animals will be harmful

Requirements of Dairy Cattle Mineral Supplements

The question now arises as to whether these mineral mixtures (Table 17-2) can also be used in the case of producing dairy cows or with beef animals being fed grain, particularly where it is desirable for convenience and for the regulation of intake to incorporate the minerals in the meal mixture Here our calculations must include the contribution of the meal allowance to the total requirement Table 17-1 indicates that beef animals receiving liberal meal allowances to permit fattening may receive enough phosphorus without special mineral supplementation However, much depends on the nature of the roughage in this case If, for example, the roughage consists largely of corn cobs, its phosphorus content may be negligible (corn cob meal carries only 0 02% phosphorus), and so, although the meal may supply appreciable amounts of this element it may have to be further fortified with phosphorus to make good the extreme deficiency in the roughage Referring to Table 17-1 again we can see that if the roughage cannot be depended on as a measurable source, a supplementary intake should be provided of perhaps 5 gms of phosphorus daily

The voluntary daily salt intake by beef cattle of from 15 to about 40 gms appears to be normal Thus if the mineral supplement is to be incorporated in the meal mixture, levels to provide 25 gms daily would not appear to be objectionable On this basis the mineral supplement could be composed of 2 parts of phosphorus carrier to 1 of salt as shown in Formula No 1 of Table 17-2

Lactation Demands. For the dairy cows, lactation requirements will constitute an additional factor With milking cows it is probable that the roughage used will be somewhat higher in phosphorus than

for range beef cow or dry dairy stock. In addition, the meal ration will appreciably contribute to the phosphorus intake even to providing a surplus over maintenance needs. The N.R.C. Feeding Standard calls for 0.7 gms. of phosphorus for each pound of milk produced. Babcock long ago suggested that one gram of salt be added to the ration for each pound of milk. Feeding standards also recommend an extra 7 gms. of phosphorus daily during the last three months of pregnancy.

From this evidence we can calculate as an example the probable maximum need for supplemental phosphorus and salt for a 1000 lb. cow producing 30 lbs. of milk and receiving 20 lbs. of average roughage plus 8 lbs. of a 16% protein meal mixture daily.

	Phosphorus	Salt
Requirement:		
Maintenance	10 gms.	15 gms.
Pregnancy	7	0
Production	21	30
Total	38	45
Supplied in:		
Roughage	9	0
Meal	19	0
Supplement needed in 8 lbs. meal	10	45

If the phosphorus carrier contains 10-12% of phosphorus then the cow of our example will require supplementary additions to her daily meal of 80-100 gms. of phosphorus carrier plus 45 gms. salt. These proportions of phosphorus to salt are those of Formula No. 1, Table 17-2. If the daily meal is 8 lbs. (as above) then it will require about 36 lbs. of such a supplement per 1000 lbs. of meal mixture, of which 12 lbs. would be salt. This is slightly more than the 1% which the N.R.C. Standard indicates will usually meet requirements. Also, such a mineral supplement, if used at a level of 3% of the meal will provide 15% less phosphorus than shown as needed in our calculation. We should note, however, that an allowance to cover pregnancy was included in the example. This extra is called for in feed-

ing standards only during the last three months of pregnancy Deleting this extra allowance of phosphorus would reduce the calculated daily bone meal requirement some 25% during most of the lactation period Consequently, the inclusion in the milking cow meal mixture of 3% of Formula No 1, or of 2% of Formula No 2 (Table 17-2), can be expected to meet the needs as nearly as is demanded in practical feeding practice

Mixed Mineral Supplement for Swine

The problem of arriving at the basic makeup of the swine mineral supplement is not complicated by the matter of a variable roughage contribution to the elements needed With swine the major mineral, other than common salt, which is likely to be needed in supplementary amounts, is calcium Because of the grain intake the phosphorus requirement is usually met from this source

Calcium Carriers. Calcium carriers can be roughly divided into two groups The one includes products that do not also contain phosphorus These furnish 36 to 40% of calcium, chiefly in the form of calcium carbonate The other group is made up of calcium phosphates, and these run from about 23% for the raw feeding bone meals to 30% for edible steamed bone meal, with the various rock phosphates falling within this range

Thus, since the salt requirement is relatively a constant, it may be desirable to consider two basic formulae differing according to which type of calcium carrier is to be used

As with cattle mineral supplements the amounts of the trace minerals may conveniently be expressed quantitatively in relation to the salt Inclusion or omission can be at the expense of the calcium carrier without measurable harm to the usefulness of the mixture

Calcium–Salt Ratio. The proportions of the calcium carriers to salt can be calculated directly from the 1953 N R C Feeding Standard The quantities of the other ingredients have also been taken from

this standard or, where necessary, from data in the more recent literature (see Table 17-3).

TABLE 17-3 *Flexible Formula for Swine Mineral Supplements (Figures are pounds unless otherwise noted)*

Source of mineral elements	% of element in source	No. 1 Using high Ca carriers	No. 2 Using low Ca carriers
Calcium carbonate	40 Ca		
Oyster shells	38 Ca	75*	
Ground limestone (high Ca)	36 Ca		
Steamed bone meal (edible)	30 Ca		
Raw feeding bone meals	23 Ca		85*
D-calcium phosphate	23 Ca		
Rock phosphates	23-30 Ca		
Salt (NaCl)		25	15
Trace minerals (to be added at the expense of the Ca carrier)			
Ferrous sulfate	37 Fe	130 gms.	80 gms.
Copper sulfate	25 Cu	6 gms.	4 gms.
Potassium iodide	76 I	8 mgs.	5 mgs.
Zinc chloride	48 Zn		
Quantity of mixed supplement to include in each 1000 lb. batch of ration		20 lbs.	33 lbs.

* Minus total of trace minerals.

SUGGESTED READING

A series of individual pamphlets published by The Committee on Animal Nutrition, U.S. National Research Council, 2101 Constitution Ave., Washington, D.C.

Nutrient Requirements of Domestic Animals.

Poultry (1950)
Swine (1953)
Dairy Cattle (1950)
Beef Cattle (1950)
Sheep (1949)
Horses (1949)

Feeders Guide and Formulae for Meal Mixtures Quebec Provincial Feed Board E W Crampton Secretary Prov Dept of Agr Quebec Can (1955)

Geurin H B et al Cob Portion of Ground Ear Corn as Sole Roughage for Fattening Cattle *J Animal Sci* V 14 No 3 p 797

CHAPTER 18

Flexible Formulae for Cattle Meal Mixtures

TO ARRIVE at a basic formula for cattle mixtures the same procedure in principle as outlined in Chapter 16 may be followed. There are however two factors to be considered that were not dealt with in discussing the scheme of flexible ration formulation. The first is that quality of protein is a negligible problem in the choice of feedstuffs with herbivors, and the second relates to the protein levels of the basal feeds.

Corn vs. Barley as the Basis of Cattle Meal Rations

To be realistic, we must recognize that basal feed mixtures used in cattle feeding are esentially of two kinds. The one is based on corn (or milo), and the other is based on the coarse grains, barley and oats. Combinations in which corn predominates will not average 12% protein as used for convenience in our example in Chapter 16. They will, in fact, be closer to 10% T.C.P., unless the use of wheat bran is higher than is usually desirable. Using the analyses given by Schneider we find for corn grains figures for T.C.P. of:

9.6%
9.0%
9.3%

and the N R C Committee gives in the table of typical analyses for dairy cow feeds as used, values for D C P equivalent to T C P of 8 5% for dent and 9 5% for flint corn of No 2 grade, while the beef committee figures on corn of only 8 5% T C P Thus, if 3 parts of the basal feeds by weight were corn or milo and the balance made up of coarse grains, the basal mixture would not exceed 10% T C P If we also used molasses it would be safer to calculate the total protein of the basal category of the mixture as 9%

On the other hand, when corn does not dominate the meal mixture, either barley or oats are likely to be emphasized, with the result that the basal feed combination will usually carry close to 12% of T C P

Thus it would seem worthwhile to present two flexible formulae, one based on heavy corn feeding and the other on coarse grains The difference between them will be in the proportions of basal feeds to protein supplement, the minerals remaining the same in each This division will also *roughly* separate, for meal rations of the same protein level, beef cattle and dairy cattle mixtures in the sense that the former perhaps more than the latter will tend to emphasize heavy corn or milo feeding

Protein Level of the Formula

From previous discussions it seems evident that three dairy cattle mixtures must be considered One would be for young animals and might well be called a calf meal and the evidence is that it should carry at least 20% of T C P We have also shown that other classes of dairy cattle fed according to standard feeding practice should have meal mixtures carrying either 16% or 18% of T C P In addition, one of 14% should be included for some classes of beef cattle Of these three the 16% is probably the most popular, and it may, therefore, be logical to deal first with a meal mixture of this protein level

In these formulae it will be well to subdivide the protein supplements, one group to include the oilmeals where the protein content

ranges from 30-45%; the other to include the distillery and brewery by-products where the protein ranges from 20-30%.

Feedstuffs Included. The feedstuffs most often used in the preparation of cattle meal mixtures have been included in this formula, and typical total crude protein and total digestible nutrient figures to the nearest whole percentages have been entered opposite each of the feeds listed (excepting for the mineral supplements). For simplicity the mineral component has been shown only in total pounds of one or another of the supplements discussed in Chapter 16 and shown in Table 17-3.

In the column headed "Recommended Formula" we have shown the quantities of the several feeds making what might be considered as a first choice combination. The first choice means merely that if neither price, availability, nor any other features (except nutritional usefulness) are factors, these quantities might be considered to give a mixture having fewer peculiarities limiting its use than many other combinations we could make. It is a sort of guide in the use of the possible substitutions.

In the columns headed "Minimum Limit" and "Maximum Limit" are figures intended to aid in preparing satisfactory combinations where factors other than, or in addition to, nutritional properties must be considered. Table 18-1 presents a completed, flexible formulae for a 16% protein cattle meal mixture in which the basal feed combination to be used is expected to average 10% total crude protein.

Proportions of Groups. The proportion of the main groups may be arrived at as follows. It will be convenient and reasonable to consider that the oilmeals will average 40% and the distillery-brewery by-products about 25% T.C.P.; and that in practice we might use 2 or 3 parts of the former to one of the latter. Thus the mixed protein supplements would, in practice, average about 35% T.C.P. Therefore, we could calculate for the 10% T.C.P. basal feed combinations the proportions of the formula in a 1000 lb. mix as:

Basal feeds plus 20 lbs of minerals } 10% → 19 parts = { 740 lbs. basal feeds, 20 lbs. minerals }

16%

Protein supplement } 35% → 6 parts = 240 lbs. protein feeds

25 parts — 1000 lb batch

TABLE 18-1 *Flexible Formula for 1000 Lbs. of a 16% Protein Cattle Meal Mixture (Basal feeds averaging 10% protein)*

Main Groups	Subgroups	Feedstuffs: Name	T.C.P.	TDN	Min. limit	Max. limit	Recommended formula
Basal Feeds (av 10% protein) 740 lbs		Hominy feed	11	85	0	400	
		Corn	9	80	500	600	500
		Milo	11	80	0	500	
		Wheat	15	83	0	240	
		Barley	13	71	0	240	
		Wheat shorts	17	64	0	240	
		Oats	12	66	0	240	
		Wheat bran	16	57	0	240	130
		Molasses	3	72	0	80	80
Protein Supplements (35% protein) 240 lbs	(30 45% protein) 160 lbs	Peanut oilmeal	44	80	0	100	
		Gluten meal	41	76	0	100	
		Linseed oilmeal	36	76	0	160	
		Soybean oilmeal	44	73	0	160	90
		Cottonseed meal	41	79	0	100	100
	(20 30% protein) 80 lbs	Corn dist grains	27	81	0	80	80
		Gluten feed	25	75	0	80	
		Brewers grains	22	60	0	80	
Minerals 20 lbs		No 2 Mix (Table 17 2)			20	20	20
Vitamins		Vit A (as carotene)				10 gms	10 gms

Table 18-2 presents another 16% protein cattle meal mixture formula based on the use of a selection of basal feeds that will average 12% protein. It will meet conditions where the coarse grains and

TABLE 18-2 *Flexible Formula for 1000 Lbs. of a 16% Protein Cattle Meal Mixture (Basal feeds averaging 12% protein)*

Main Groups	Subgroups	Feedstuffs Name	T.C.P.	TDN	Min. limit	Max. limit	Recommended formula
		Hominy feed	11	85		200	
		Corn	9	80		200	
Basal Feeds		Milo	11	80		200	
(av. 12%		Wheat	15	83	0	300	
protein)		Barley	13	71	300	500	400
790 lbs.		Wheat shorts	17	64		250	
		Oats	12	66	150	400	310
		Wheat bran	16	57	0	200	
		Molasses	3	72	0	80	80
	30-45%	Peanut oilmeal	44	80	0	70	
	protein	Gluten meal	41	76	0	70	
Protein		Linseed oilmeal	36	76	0	130	60
Supplements	130 lbs.	Soybean oilmeal	44	73	0	130	70
(35%		Cottonseed meal	41	79	0	70	
protein)	20-30%	Corn dist grains	27	81	0	50	
180 lbs.	Protein	Corn Gluten feed	25	75	0	50	
	50 lbs.	Brewers' grains	22	60	0	50	50
Minerals		No. 1 Mix					
30 lbs.		(Table 17-2)					30
Vitamins		Vit. A (as carotene)				10 gms.	10 gms

perhaps also wheat will be more economically available than will corn or milo grain.

It may be well now to examine the make-up of these meal mixtures in some detail.

Basal Feeds. In these formulae nine commonly used feeds belonging to the low-protein category are included They have been listed roughly in descending order of their TDN contents With the exception of molasses, differences in protein between these feeds, from the practical feeding standpoint, are relatively minor All the other feeds carry between 9 and 16% protein, and we know from experience that mixtures of them, as found in practical rations, usually work out to about 9% protein in corn feeding areas and 12% where coarse grains are emphasized

Maximum Limits. The figures set in the maximum column are such that at least two feeds must be used from the basal category We might argue that it doesn't matter whether there is more than one basal feed in the cattle meal mixture or not, and theoretically this statement is true It is also equally true that a mixture that contains more than one basal feed may be less restricted in its use, since the characteristics of any one feed do not predominate Most feedstuffs have unique properties that limit their unrestricted use, especially in dairy cow rations Skilled feeders who prefer to employ larger than the maximum limits set for any one of these products can do so But for the less experienced, a mixture of basal feeds is partial insurance against a ration that might be somewhat undesirable in specific cases

Specifically the use of over 500 lbs of *hominy* or of *corn* in a 1000 lb mix will tend to produce a heavy ration, which, if fed in large amounts, may have more of a tendency to put animals "off feed' than a bulkier ration might do More than 500 lbs of *barley* will sometimes render a ration somewhat unpalatable so that large allowances will not be readily eaten by high producing animals requiring liberal feed This unpalatability is more often due to the presence of weed seeds or other 'dockage" than to the pure barley Consequently, the problem is one of the quality of barley used With samples of barley of high purity and free from heat or weathering damage, the 500 lb maximum can safely be lifted *Wheat*, if fed in quantities much over one-third of the ration, tends to produce a heavy, pasty and somewhat unpalatable ration especially if finely ground

Oats, on the other hand, if included as much more than 40% tends to result in a mixture of undesirably low TDN content, and of which a correspondingly larger allowance must be fed to meet specified energy requirements. *Wheat bran,* for the same reason, is limited to 25% of the total ration. Even this amount of bran, unless counterbalanced by some of the heavier feeds, will result in too bulky a ration for normal feeding levels.

Experimental evidence indicates that 8% *molasses* in a meal mixture is about all that can safely be incorporated without the danger of the feed becoming lumpy on storage and in some cases of turning sour, especially during warm weather.

Minimum Limits. The minimum limits that have been incorporated for the basal feeds present a somewhat different problem. One might put zeros for all of these feeds and justify it on the grounds that the maximum limits already require two feeds to be used, together with the fact that nutritionally the choice of feeds is probably almost immaterial. On the other hand, setting no minimums would make it possible for the basal portion of this ration to consist entirely of corn and wheat. Such a combination in the eyes of most practical dairy cow feeders would be undesirable, though beef feeders might not object to it. The feed would be heavy and tend to be pasty. Consequently, minimum limits have been set in the "coarse grain" formula for barley and oats—two feeds, which together can constitute a satisfactory dairy cow meal mixture insofar as the basal feeds are concerned—which when used in combinations with the heavier feeds will correct the undesirable physical properties of the latter. The maximum limit set for oats prevents its use beyond half the basal feeds. This is insurance that the ration will not be too light and bulky, even if the combinations of barley and oats should constitute the whole of the basal feed section.

We should call attention to the fact that no minimum appears for *wheat bran,* in spite of the fact that in some districts feeders seem to be of the impression that it should not be omitted from a dairy ration under any circumstances. Bran has a particularly high phosphorus content, and if feeders do not wish to use phosphorus-con-

taining minerals, they may use bran to help prevent phosphorus deficiency However, the feed is exceedingly bulky and its inclusion in any appreciable proportion in the meal mixture increases unduly the quantity of feed required to meet given energy needs

High Protein Feeds. In these pattern mixtures we have indicated that four protein feeds are preferred Here, again, using more than one is not a nutritional necessity, especially in the preparation of a ready-to-feed mixture Several feeds have been included, however, but for another purpose From this 16% formula can be derived a mixed mineral protein supplement suitable for use in preparing cattle meal mixtures at home with farm grown grains Where such supplements contain a variety of feeds they are less likely to have peculiarities that might limit their use with some combinations of farm grains

Note in connection with the protein supplements that the ratio of the oilmeal group to the lower protein group is fixed in order to give a final combination of 35% protein Finally, commercially prepared mixed protein supplements normally involve a variety of feedstuffs so that price fluctuations can be cushioned by adjustment of proportions of the feeds used

Among the oilmeal group there is no preference between linseed oilmeal or the soybean oilmeal insofar as the nutritional properties are concerned There may be some reason however, to limit peanut oilmeal and cottonseed oilmeal somewhat, because these products have different qualities This is especially true with cottonseed meal Insofar as gluten meal is concerned the amounts that can be used are limited because of its physical nature It is a heavy concentrated type of feed, and if combined with corn or hominy will result in a mixture heavier than is desired for best dairy cattle feeding

With the 20-30% protein subgroups we have indicated no choice between the three feeds listed We should point out, however, that whereas corn distillers grains and gluten feed carry around 80% TDN brewers' grains are decidedly light and bulky Consequently, brewers grains when used should not be combined with feeds of the basal group that are also on the light side Obviously, therefore, there

can be no minimum limit set within either subgroup for any of the common feeds.

Mineral and Vitamin Supplements. Of the 20 or 30 lbs. of mineral supplements that are called for in these formulae, the amount of salt is fixed at 10 lbs. per thousand of complete ration (see also Chapter 16).

Whether or not it is necessary to add any Vitamin A and D supplement to a mixture of this kind will be questioned by different authorities. Primarily it will depend on what kind of roughage is being fed and whether or not cattle are exposed to ultra-violet rays of the sun. We do know, however, that Vitamin A, or its precursor carotene, is critical during the last part of the pregnancy period in connection with the normal development of the calf, but if requirements for the maintenance of the cow and her fetus are met there is no evidence that additional amounts will be necessary to maintain maximum lactation. However, the concentration of Vitamin A in the milk will be dependent to some extent on the amount of Vitamin A in the cow's ration in excess of her maintenance needs. Consequently, in these formulae 10 grams of carotene or its equivalent in Vitamin A, are recommended as a minimum inclusion. This should be sufficient to supply the maintenance requirements plus the pregnancy requirements without any Vitamin A coming from the roughage. Any quantities in excess of this figure as supplied by the roughage will contribute toward a high Vitamin A content of the milk produced.

Insofar as Vitamin D is concerned there is no evidence on which to base a probable requirement. It is believed that Vitamin D is required, but it is also believed that under normal conditions an adequate quantity is supplied through sun-cured roughage, particularly if cattle during a part of the year are on pasture and hence exposed to direct rays of the sun. Consequently, no figures are included in these formulae for Vitamin D; nor are there any other vitamins which are needed as supplements in the preparation of meal mixtures for cattle stock.

A Protein Supplement for Use in Preparing Cattle Meal Mixtures

Referring to the 16% protein flexible formulae on page 362, we can see that the ration consists of three major groups of feedstuffs The first includes the basal feeds, the next is the protein supplement fraction, and the third the mineral supplement Each of these may be considered as units, and if the protein group and the mineral group are expressed on the basis of a 1000 lb and a 100 lb batch respectively they become useful in preparing meal mixtures of differing protein levels Tables 18 3 and 18-4 show these protein and mineral mixed supplements

TABLE 18-3 *Flexible Formulae for a 35% Protein Supplement for the Preparation of Cattle Balanced Meal Mixture*

Group Totals (approx)	Maximum limits as in 16% protein formulae		Feedstuffs	Expressed on 1000 lb basis	
	Table 18 1	Table 18 2		Average Maximum	Recommended
	100	70	Peanut oilmeal	380	—
	100	70	Gluten meal	380	—
70%	160	130	Linseed oilmeal	710	210
	160	130	Soybean oilmeal	710	250
	100	70	Cottonseed meal	380	250
	80	50	Corn distillers grains	290	—
30%	80	50	Corn gluten feed	290	290
	80	50	Brewers grains	290	—

Flexible Formula for 18% Dairy Cow Meal Mixture

One of the simplest ways of preparing an 18% dairy cow meal is by modifying the proportions of protein and mineral supplements found in the 16% formula As we showed in Chapter 16 this is very simply done by considering the basal and the mineral groups as one

The protein supplement carries 35% protein. Hence, for an 18% protein mixture, we calculate (using basal feeds averaging 12% protein):

Basal feeds plus 30 lbs. of minerals } 12% → 17 parts = { 710 lbs. basal feeds, 30 lbs. minerals

18%

Protein supplement } 35% → 6 parts = 260 lbs. protein supplement

1000 lb. batch

Such a mixture can be made by using the same possible substitutes among the basal feeds as was indicated with the original 16% formula, and, of course, the formula for the mixed protein supplement can also be modified through the use of alternative products, as indicated in the flexible formula for the supplement.

Using the Protein and Mineral Supplement. If we wish to prepare a 14% protein ration for cattle, such as might be useful for fattening beef stock, or for dry dairy cows, or for cows on pasture, we may use the same procedure. These possibilities are shown in Table 18-4.

TABLE 18-4 *Proportions of Feed Groups to Prepare 1000 lbs. of Cattle Meal Mixtures of Different Protein Levels*

% protein wanted in final mixture	Basal feeds of 12% protein			Basal feeds of 10% protein		
	Basal feeds	Protein suppl.	Mineral suppl. No. 1	Basal feeds	Protein suppl.	Mineral suppl. No. 2
14	880	90	30	820	160	20
16	790	180	30	740	240	20
18	710	260	30	640	340	20
20	620	350	30	560	420	20

Hints for Formulation of Cattle Meal Rations

Typical flexible formulae for meal mixtures suitable for feeding cattle have been given in the preceding pages However, it is possible by selections within the permitted tolerances to compound meal mixtures having undesirable characteristics Accordingly, the following hints may be useful in avoiding such situations

The *fiber* content of the meal mixture should probably seldom exceed 12% As the fiber content increases appreciably above this level, the TDN of the mixture is likely to be lowered enough to affect the quantities of feed that have to be consumed to meet energy requirements A fair guide in this respect is to see that the meal mixture does not weigh less than 8 lb per quart When making such measurements pour the meal mixture into a quart measure, or other container* to be used, until the measure overflows Then with a small stick push off with one pass the feed that lies above the level of the rim of the measure *Do not pock the feed*, either by pressure or by agitation of the measure It will also be desirable to take 3 or 4 tests on the same feed to get a reliable weight per quart figure An erroneous measure will be misleading as to the TDN in the mixture

Avoid the *fine grinding* of cattle feeds Experiments indicate that grains that have been broken into three or more pieces are just as digestible as though they had been finely ground Coarsely ground feeds are more palatable to cattle than fine material Grinding oat hulls or straw into a powder hides them in a meal mixture, but does not make them any more valuable for feeding Some commercial mixtures for cows are now prepared by rolling or crushing a portion of the materials and pelleting the finer particles in order to avoid the dusty nature of finely ground products

Though useful in small amounts when available at economical prices, *wheat bran* is not an essential ingredient in a satisfactory dairy cow meal ration It should always be restricted to 25% or less of the total mixture regardless of any other consideration, largely

* Preferably one that is relatively deep for its diameter

because of its low TDN and consequently its diluent effect on the useful energy of the meal mixture.

Flexible Formula for 22% Protein Calf Meal (Calf Starter)

The flexible formulae we have presented so far in this chapter have been for meal mixtures intended for cattle stock over six months of age. More specifically they are suitable for animals after an age at which the rumen has become fully functional. They are normally fed in conjunction with roughage, which represents from half to nearly all of the total ration.

It now remains to present a formula of a type suitable for young dairy animals—animals from one month and perhaps up to six months of age. For the youngest calves such a mixture will be a possible milk substitute where animals are weaned from milk between 21 and 30 days of age. As such the mixture can be made into a water gruel for feeding; or it may be fed, preferably in pellet or crumble form, as a dry feed, if this is the calf-raising scheme being followed.

As with the previous flexible formulae, some latitude is permitted in the selection of the feedstuffs, but the substitutions are fewer and more restricted than with rations for older animals. This restriction is a reflection of more critical nutritional requirements plus much less factual information regarding the needs of animals of this category. The recommended formula has been found in practice to be satisfactory, but how far it can be modified through ingredient selection is not known. The maximum and minimum limits are therefore based on the general nutritional properties of the feeds rather than on any practical experience with combinations that can be made.

Substitutions and Special Additives. Among the basal feeds there are few restrictions on substitution. The feeds shown are interchangeable within wide limits for all classes and ages of farm animals. In general, however, the *maximum of oats* should not be employed with the younger calves because of the fiber content.

TABLE 18-5 *Flexible Formula for 22% Protein Calf Meal (Calf Starter)*

Major groups	Subgroups	Feedstuffs	Minimum lb/t	Maximum lb/t	Recommended
Basal Feeds 590 lbs (12% protein)		Oat groats	0	250	200
		Hominy feed	0	250	
		Corn	100	250	100
		Wheat middlings	50	115	115
		Oats	100	300	100
		Molasses	0	75	75
Protein Supplement 380 lbs	(43% protein) Total 320 lbs.	Soybean oilmeal	100	250	125
		Linseed oilmeal	0	150	125
		Whitefish meal	25	50	30
		Meat meal	0	30	30
		Skimmilk powder	5	50	10
	(24% protein) Total 60 lbs	Dried brewers yeast	5	10	10
		Dried cereal grass	25	50	50
		Alfalfa leaf meal	0	50	
Minerals 30 lbs		Bone meal	20	20	20
		Fine salt	10	10	10
		Potassium iodide	0	.6 gm	6 gm
		Cobalt sulfate	0	1.5 gms	1.5 gms.
Vitamins	Added to 1000 lb mix	Riboflavin (μ)	2 000 000	?	2 000 000
		Carotene	0	3 gms	3 gms
		Vitamin A (I.U.)	0	10 000 000	
		Vitamin D (I.U.)	2,000 000	?	2 000 000
		Vitamin B_{12}	0	5 mgs	
		Antibiotic	20 gms.	?	20 gms.

It is in the protein supplements that more judgment must be exercised, since quality of protein is an important factor Calves of this age group should not be considered to be independent of ration sources of essential amino acids

There is general agreement that of the plant sources *soybean*

proteins are of higher biological value than the others, except for *wheat germ* or *corn germ* where only the embryo proteins are involved. Lysine and/or methionine will usually be the important limiting amino acids with most feeds of plant origin. To enhance this deficiency low fat *fish meal* and *meat meal* have been included, with the former carrying a minimum figure. As an added protection against low quality, a minimum of 5% of *skimmilk powder* is also called for.

Three potential natural sources of the Vitamin B complex are included, two of which carry minimum figures. Either the cereal grass or the alfalfa leaf meal will also provide carotene.

In addition to the natural feedstuffs this formula is spiked with pure riboflavin, and carotene (or Vitamin A); and with concentrates of Vitamin D, and an antibiotic. This group of additives is, in general, included without much basic knowledge of the quantities actually required, and the values given are therefore subject to revision (probably downward) as more information becomes available. We do not believe that any excesses the figures may represent are likely to be incompatible with normal health or the normal development of calves. There is some doubt whether B_{12} is needed. We have entered it in the formula only to indicate its maximum limit if it is to be included.

A calf starter meal would normally be discontinued for reasons of economy in favor of an 18%, or after an age of 12 months a 16% protein cattle meal mixture, though there is no nutritional reason for making such a change.

The Flexible Formulae in Practice

That the mixing formulae for commercially prepared balanced rations vary from time to time in accordance with fluctuations and availability of ingredients is no secret. Indeed, one of the older arguments for home mixing of feeds was that those made commercially to closed formula were never twice the same. The obvious implication was that change in formulae was nutritionally undesirable. Such arguments are not often heard today, the principle of legitimate feed substitution being recognized as immaterial nutritionally, and a practical necessity economically. Feeders generally, however, have

little idea of how often or to what extent the mixture formulae are actually changed The fact that the performance of the animals is not altered detectably in consequence of such changes is practical evidence that the feeder need not worry about them

As a matter of interest, however, a tabulation of the authentic formulae of one of the leading feed manufacturers in Canada of their first grade 16% protein dairy cow meal mixture over a 2-year period from April 1953 to April 1955 is shown in Table 18-6 The month when each change occurred is also shown The small quantity of trace minerals in the formulae has been omitted, however, since it was constant It will be noted that the quantities of bran and shorts have been essentially constant and reflect a constant supply of a by-product of their own flour milling operations Molasses, added largely for its favorable effect on the physical nature of the ration, has fluctuated but little Then, as we examine the formulae further, we can see that the minerals have been constant except for a change from bone meal to dicalcium phosphate The protein supplements, however, have been exchanged to varying degrees As a matter of insurance against local shortages of individual feeds several protein feeds have been included and, consequently, the absolute amounts involved in an exchange of 50% of the gluten for a like amount of distillers' grains would involve only 40 lbs of either one per ton of ration Such changes could not be expected to be of nutritional significance in any one mixture But in the overall feed mill operations with a full line of mixed feeds, cutting in half the quantity of gluten used might easily involve several carloads of the ingredient over a relatively short time period

Among some of the feeds, however, there have been more drastic substitutions For example, in one case, 300 lbs of screenings were replaced abruptly by 200 lbs of barley plus 100 lbs of wheat, in another, 100 lbs of bran was replaced by 100 lbs of oats Also 120 lbs of linseed oilmeal was replaced by 60 lbs each of cottonseed and rapeseed oilmeals

Altogether 20 ration changes have been made, or about one a month though not on any schedule, but rather largely according to ingredient price By such procedures the selling price to the feeder can

TABLE 18-6 *Showing Formula Changes Over a 2-yr. Period in a 16% Dairy Meal Mixture*

Ingredient	1953										1954						1955			
	Feb.	Feb.	Apr.	May	June	June	June	June	Aug.	Oct.	Jan.	Feb.	Mar.	July	Sept.	Oct.	Feb.	Mar.	Apr.	May
Molasses	10	10	10	10	10	9	10	7	7	7	7	7	7	7	9	9	9	9	9	9
Barley	5	5	5	5	5	5	15	15	15	15	15	15	15	15	15	15	20	20	20	20
Oats	15	15	15	15	15	15	20	20	20	20	20	20	20	20	18.5	18.5	13.5	18.5	18.5	16.5
No. 1 Screenings	15	15	15	15	15	15														
Bran	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	10	10	12
Shorts	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Linseed O.M.	4	4	6	5	6	8	7	9	5	3	3	3	5	5	6.5	3	3	3	3	3
Cottonseed O.M.									4	3	3	3								
Rapeseed O.M.	2	3	1	1	1	1				3	3	3	4	4	4	3	3	3	3	3
Gluten Feed	3	3	2	3	3	4	4	7	7	7	5	5	5	5	4	4	4	4	6	4
Brewers' Gr.	2	2	3	3	3	3	3	3	3	3	3	5	5	4	4	4	4	4	4	4
Dist. Gr.	4	4	3	3	4	4	3	3	3	3	3	3	3	3	4	4	4	4	4	4
Malt Sprouts	2	2	2	4	3	3	3	3	3	3	4	3	3	4	4	4	4	4	4	4
Clover Scrngs.	10	9	10	8	7	5	7	5	5	5	5	5	5	5	3	7	7	7	5	7
Dical. Phos.														1	1	1	1	1	1	1
Bone Meal	1	1	1	1	1	1	1	1	1	1	1	1	1							
Gr. Limestone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Urea																.5	.5	.5	.5	.5

be kept reasonably stable Maintenance of volume of sales and particularly maintenance of repeat sales is evidence that feed substitutions are in the best interests of all concerned

SUGGESTED READING

Feeders Guide and Formulae for Meal Mixtures Quebec Provincial Feed Board E W Crampton, Secretary, Prov Dept of Agr, Quebec, Can (1955)

CHAPTER 19

Flexible Formulae for Swine Meal Mixtures

DATA PRESENTED in Chapter 15 indicate that meal mixtures of three different protein levels are required for swine. Of the three, the 15% mixture will normally be required in the largest quantities in any pig feeding program. Accordingly, it may be well to deal with this mixture first.

Two 15% Protein Flexible Formulae for Swine Meal Mixtures

Table 19-1 gives a flexible formula for a swine meal mixture carrying 15% of total crude protein. The basal feeds are to carry 12% T.C.P. A second formula where the basal feeds combination carries only 9% protein is shown in Table 19-2. A considerable selection of basal feeds has been included in the formula for reasons that will be evident shortly. Also, some of the animal protein group are included, because with swine we have to select feeds that will assure the presence of essential amino acids. As with cattle rations, little choice is given in connection with the minerals and none with the vitamin supplementation.

The maximum limits of individual basal feeds has been set so that at least two basal feeds must be employed. This variety among the basal feeds is not likely to be of any consequence in correcting

TABLE 19-1 *Flexible Formula for 15% Protein Swine Meal Mixture (Basal feeds to average 12% protein)*

Main groups	Subgroups	Feedstuffs	Minimum limit	Maximum limit	Recommended
Basal Feeds 875 lbs (av 12% protein)	Grains 625 lbs minimum	Oat groats	0	100	
		Rice polish	0	100	
		Wheat	0	300	
		Hominy feed	0	500	
		Corn	0	500	200
		Rye	0	200	
		Barley	200	500	300
		Feed flour	0	100	
		Oats	100	375	200
	Mill feeds 250 lbs maximum	Shorts (standard middlings)	0	250	175
		Wheat bran	0	200	
Protein supplements (av 45% protein) 110 lbs	Plant origin 80 lbs	Peanut oilmeal	0	50	
		Soybean oilmeal	0	80	
		Cottonseed meal	0	50	
		Linseed oilmeal	0	80	80
		Brewers' yeast	0	50	
	Animal origin 30 lbs	Fish meal	10	30	15
		Meat meal	0	30	15
		Skimmilk powder	0	30	
		Buttermilk powder	0	30	
Minerals 15 lbs		Mixture No 1 (Table 17-3)	15	15	15
Vitamin Antibiotic Supplement		Vitamin A (i u)	800,000	1,000,000	800,000
		Vitamin D (i u)	900	1,000	900
		Vitamin B_{12} (mgs)	5	10	5
		Antibiotic (mgs)	5	10	5

TABLE 19-2 *Flexible Formula for 15% Protein Swine Meal Mixtures (Basal feeds to average 9% protein)*

Main groups	Subgroups	Feedstuff	Minimum limit	Maximum limit	Recommended
Basal Feeds (av 9% protein) 790 lbs	Grains 540 minimum lbs	Oat groats	0	100	
		Rice polish	0	100	
		Wheat	0	300	
		Hominy feed	0	300	
		Corn	490	790	790
		Rye	0	200	
		Barley	0	300	
		Feed flour	0	100	
		Oats	0	200	
	Mil' feed 250 maximum lbs	Shorts	0	200	
		Wheat bran	0	200	
Protein Supplement (av 45% protein) 195 lbs	Plant origin 140 lbs	Peanut oilmeal	0	90	
		Soybean oilmeal	90	140	80
		Cottonseed oilmeal	0	90	
		Linseed oilmeal	0	90	60
		Brewers yeast	0	50	
	Animal origin 55 lbs	Fishmeal	20	55	25
		Meatmeal	0	55	30
		Skimmilk powder	0	55	
		Buttermi'k powder	0	55	
Minerals 15 lbs		Mixture No 1 (Table 17-3)	15	15	15
Vitamin Antibiotic Supplement		Vit A (i u)	800,000	1,000,000	800,000
		Vit D (i u)	900	1,000	900
		Vit B_{12} (mgs)	5	10	5
		Antibiotic (gms.)	5	10	5

low quality of protein, however, since all basal feeds are deficient in lysine

The Protein Supplements

Only one high protein feed of the plant group has been put into one of the final formulae Many would question the choice of *linseed oilmeal* in this position In some districts where *soybean oilmeal* is an important and economical feed, it might well be chosen in preference to linseed oilmeal However, inasmuch as the use of soybean oilmeal will not fully correct the low biological value of the basal feeds, the choice of the high protein feed from the plant group will not be critical

The quantities of *meat* and *fish meal* are such that at least 10% of the total protein of the ration will come from these two sources Here we should note that there is a minimum limit set on fish meal The reason for this comes from experimental evidence indicating that when high grade fish meal is included in the ration, the performance of the pigs tends to be somewhat better than when it is omitted, even though meat meal is also included

Brewers yeast has been included as a possible choice up to 5% Price will normally keep this feed at a minimum if it is used at all Brewers' yeast is high in pantothenic acid and wherever "goose-stepping or incoordination in the gait has been found with growing pigs the use of some source of pantothenic acid has frequently corrected the trouble Swine rations based largely on barley and oats tend to be borderline in this vitamin Consequently, it is included as a possible selection Since it furnishes about 40% protein it is correctly classed in the protein group

The mineral supplement is that discussed and formulated in Chapter 17 (see Table 17 3)

The quantities of Vitamin A and Vitamin D we have recommended represent the evidence that is available at present These quantities are likely to be revised downward as further information becomes available The Vitamin A can, of course, be replaced by its equivalent in carotene

The amounts of Vitamin B_{12} which are included are essentially one-half the probable daily requirement. This figure has been set on the assumption that fish meal and meat meal will probably carry sufficient B_{12} to meet the remainder of the requirements. Somewhat the same line of reasoning has determined the level of antibiotic we have recommended.

The formula represented by the figures in the "recommended column" is essentially one that has been used in practice for many years and has given excellent results. It is, however, only a guide as to what type of selection should be preferred if no other considerations are involved.

Protein-Mineral-Vitamin Supplement for Use with Home-Grown Feeds

The 15% protein formula above can be separated into two parts. Deletion of the basal feeds and restatement of the quantities of the other feeds in terms of 1000 lb. batches will form the basis for flexible formulae for a 45% protein supplement. This is shown in Table 19-3; and Table 19-4 gives the proportions of the basal feeds, and the protein and mineral-vitamin supplements that should be combined to prepare mixtures of the three protein levels called for in hog feeding.

The maximum and minimum limits for the basal feeds shown in the original 15% protein formula can be used in both the 18% and the 13% mixture. However, it may be well to note that the heavier feeds should predominate in the 18% ration. Thus the minimum of *oats* would be used and *wheat bran* avoided. This ration should aim at 75% or over of TDN, and a low fiber level. On the other hand, the 13% mixture, if intended for finishing bacon hogs or for feeding to dry sows and boars, will be more satisfactory if lighter feeds are emphasized, so that the TDN does not exceed 70%; and 67% is not undesirably low. Such rations could carry the maximum of both *oats* and *wheat bran*.

The mineral-vitamin supplement is included in the same proportions in all mixtures, since these ingredients are needed more nearly

TABLE 19-3 *Flexible Formula for a 45% Protein Supplement for Swine Rations*

Group Total (approx)	Maximum limits as in 15% protein formulae		Feedstuffs	Expressed on 1000 lb basis	
	Table	Table		Average maximum	Recommended
	50	90	Peanut oilmeal	480	
	80	140	Soybean oilmeal	725	400
72%	50	90	Cottonseed meal	480	
	80	90	Linseed meal	480	225
	50	50	Brewers' yeast	250	100
	30	55	Fishmeal	275	200
28%	30	55	Meat meal	275	
	30	55	Skimmilk powder	275	75
	30	55	Buttermilk powder	275	

TABLE 19-4 *Proportions of Feed Groups to Prepare 1000 lbs of Swine Meal Mixtures of Different Protein Levels*

% protein wanted	Using basal feeds averaging 12% protein			Using basal feeds averaging 9% protein		
	Basal feeds	Protein suppl	Mineral suppl	Basal feeds	Protein suppl	Mineral suppl
%	lbs	lbs	lbs	lbs	lbs	lbs
13	970	15	15	890	95	15
15	875	110	15	790	195	15
18	820	165	15	750	235	15

in proportion to basal feeds or to total feed than to the protein supplements.

SUGGESTED READING

Feeders' Guide and Formulae for Meal Mixtures, Quebec Provincial Feed Board, E. W. Crampton, Secretary; Prov. Dept. of Agr., Quebec, Can. (1955).

SUMMARY OF SECTION IV

WE HAVE NOW completed that section of this book the subject matter of which represents the integration of the facts and beliefs regarding the food needs of our animals, with the makeup of the feeding stuffs that supply these needs. In one sense this results in expressing livestock feeding standards in terms of meal mixtures.

Theoretically, from an ideally balanced meal mixture ingredient formula, plus a suitable chemical analysis of the mixture and a statement of the daily allowances to be given to an animal, we should be able to derive the corresponding feeding standard (if that meal mixture constituted the entire diet). By the same reasoning we have attempted to derive ingredient mixing formulae from feeding standards plus the analysis of the ingredients available for such mixtures.

In practice we find it impossible to compound rations meeting exactly the quantities or proportions of nutrients set out in feeding standards, because we must deal with feeds which themselves are complex mixtures of nutrients. But we can prepare formulae for mixtures of feedstuffs which result in nutrient combinations that approximate the needs of specified animals closely enough so that the animal through its own metabolic machinery can make the final fitting, discarding the surpluses, and temporarily even making good minor shortages in the day's intake.

We have described one way of arriving at such formulae in this section. The flexibility of the scheme enhances its usefulness and its adaptability over a wide range of conditions under which livestock are fed, and its practicability is attested by the success of the commercial mixed feed industry.

SECTION V APPENDICES

The items we have included in the three Appendices are intended chiefly as reference material to furnish more detailed information in certain areas than seemed practical or necessary in the text proper.

Appendix I contains several miscellaneous feeding guides, discussions of specific feeding problems, and some tables that should be useful for practical feeding of livestock of all categories.

In Appendix II we have presented a brief discussion on feedstuffs control, and excerpts from The Feeding Stuffs Act *of Canada, and from the proposed* Uniform State Feed Bill *for the United States, sponsored by the Association of American Feed Control Officials.*

Tables of feed composition and miscellaneous conversion charts make up Appendix III.

APPENDIX 1

Miscellaneous Feeding Guides

Daily Allowances of Feed for Animals

Successful livestock feeding is not learned out of a book, and there are many skilled feeders who know little or nothing of the science underlying the feeding practices which they successfully employ There are, nevertheless, basic principles involved in livestock feeding and some of these can be reduced to rules and guides that will be useful to feeders who lack the experience or apprenticeship otherwise necessary

One of the ever present problems is how much meal should be fed per day to different animals? It is obvious that the answer depends on several factors The first is the total available energy that must be provided to the animal in question This amount is indicated by the TDN shown in feeding standards Such a figure, however, does not take into account the feeds other than the meal mixture that may also be fed to the livestock and which, of course, modifies the amount of meal that has to be fed With some classes of animals where the increase in liveweight is itself the production, the feeder has a relatively simple guide merely by watching the gains of the animal But with other classes of stock, and particularly with producing dairy cattle, body weight changes are not a direct index of whether or not the animal is receiving the correct quantities of meal Consequently, with dairy cattle feeding some guides other than the appearance or performance of the animal become of special importance

Guides to Dairy Cattle Feeding

Amounts of Meal Mixture for Dairy Cows in Milk. There have been many thumb rules proposed as guides to the quantities of meal mixture that should be provided to cattle in the milking herd These thumb rules are based fundamentally on feeding standards, and on the roughage feeding practice They are, nevertheless, guides and not fixed rules, and it may be well, therefore, to examine the requirements in some detail

We might at first thought assume that the quantities of meal required by milking cows is influenced by the size of the cow This, however, is not usually true unless some abnormal roughage feeding program is involved As we shall see shortly, if the dairy cow is fed normal quantities of roughage, she will receive from it sufficient TDN to fully meet her maintenance energy requirements In excess of this requirement there are two things that need to be considered, one is the amount of milk being produced, and the second is the stage of pregnancy In Chapter 14 we discussed the effect of kind and quality of roughage on the voluntary intake of such feed It will be evident from perusal of the data there presented that where high quality roughage is used and fed to the limit of appetite, which is usually considered desirable practice, the TDN thus obtained will meet requirements of maintenance plus sufficient extra for almost 20 lbs of milk of 4% butterfat content On the other hand, if poorer quality roughage is fed, the available energy from the forage portion of the ration may be little more than enough to maintain the animal

For purposes of determining guides to meal allowances, it is probably better to take average roughage containing about 50% TDN and to make the assumption that approximately 2 lbs of such roughage or its equivalent will be voluntarily consumed per cow per day for each 100 lbs of liveweight We can then quite simply calculate the pounds of a meal mixture that will be required to supply the energy needed by cows at different levels of production according to the per cent of TDN in the meal used The data have been calculated for a range of production levels and for meal of 70% and

of 75% TDN. These data are presented in Fig. Ap-1, from which we can see that whether a 70 or 75% TDN meal is fed, the place at which meal feeding should start is approximately after the first 10 lbs. of milk have been produced. That is, the roughage allowance should be sufficient for maintenance of the cow plus about one gallon* of milk. As the milk production level increases, the quantity of meal required increases in a linear fashion, and the rate is either one pound of meal for 2.34 lbs. of milk, or one pound of meal for 2.24 lbs. of milk, depending on whether a 75% or a 70% TDN mixture is being used. This is just another way of saying that the allowances of meal to cows in milk should be at the rate of about one pound of meal to every 2.3 lbs. (or perhaps 2⅓ lbs.) of milk produced in excess of the first gallon.

One of the commonest thumb rules quoted regarding the meal allowances for dairy cattle calls for one pound of meal for every 3 lbs. of milk produced. On the graph of Fig. Ap-1, the regression line for this ratio has been drawn in, and we can see that this level of feeding overfeeds all cows producing less than 40 lbs. of milk per day, but underfeeds cows producing over 40 or 50 lbs. of milk per day, depending on whether the meal used carries 70 or 75% of TDN. Any feeding rate that calls for meal beginning immediately with any production above zero will obviously show this same defect.

Feeding During Late Lactation. There is however another consideration affecting cows producing only small quantities of milk toward the end of a lactation. Such cows may be producing relatively small amounts of milk during the last two months of pregnancy. These cows require more meal than their milk production indicates: and, consequently a thumb rule which calls for no meal allowance for productions less than one gallon of milk is likely to underfeed them. Probably the most satisfactory way of dealing with this situation is to arrange to feed about 5 lbs. meal to such cows in excess of the quantities they require for milk production as indicated in Fig. Ap-1. Thus a cow that is within two months of term and producing only

* The Imperial Gallon used in Canada weighs 160 oz. or 10 lbs. The American Gallon used in the United States weighs 128 oz. or 8 lbs.

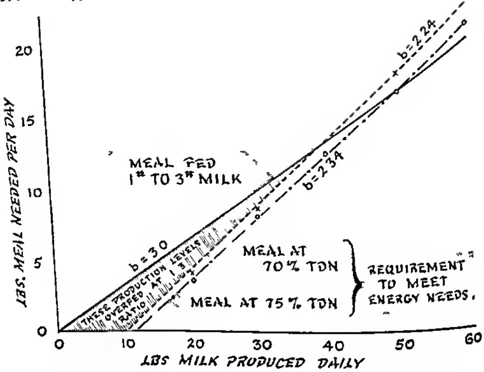


Fig Ap-1. *Pounds of meal needed per day according to pounds of 4% milk produced (Based on 1000 lb cow consuming 20 lbs dry roughage of 50% TDN or its equivalent)*

10 lbs of milk would receive 5 lbs of a normal meal mixture, in spite of the fact that her production alone would not warrant any meal at all

Thumb Rule of Meal Feeding. If we can assume therefore that production of less than 10 lbs will occur normally only toward the end of lactation, and that this also coincides with the latter quarter of pregnancy, then we might establish the rule that one pound of meal should be fed for each 2 3 lbs of milk produced in excess of the first gallon, and that during the last 60 days of pregnancy cows should receive in addition to any such allowances an extra 5 lbs of meal per day

Adjustment of Meal Allowance for Fat Content of Milk. These rules are based on milk carrying 4% of fat or its equivalent In order

to use these feeding rules with productions carrying more or less than 4% fat, the actual production should be converted to its equivalent in 4% milk. Table Ap-1 gives approximate factors for converting milk produced to its equivalent in 4% fat.

TABLE Ap-1 *For Converting Milk of a Given Fat Per Cent to Its Equivalent in Pounds of 4% Milk*

Per cent fat in milk	Factor by which to multiply milk produced to obtain pounds of equivalent 4% milk
3.0	0.850
3.2	0.880
3.4	0.910
3.6	0.940
3.8	0.970
4.0	1.000
4.2	1.030
4.4	1.060
4.6	1.090
4.8	1.120
5.0	1.150

may be replaced by about 3 lbs of silage or by 5 lbs of roots, and one-half the normal dry roughage allowance may be replaced on this basis

Feeding a Meal Mixture to Cows on Pasture. Cows on abundant good pasture will eat sufficient herbage to produce 40 lbs of 4% milk or its equivalent without other food Under these circumstances grain feeding at the rate of one pound for each 2 3 lbs of milk in excess of 40 lbs will be called for For such feeding use mixed farm grains without protein supplements, but be sure to include 1% of salt and 1% of feeding bone meal or of dicalcium phosphate in the grain used If farm grains are not available for such feeding there will be no objection, nutritionally, to the use of a standard 16% protein dairy cow meal mixture

For cows on limited or poor pasture, begin grain feeding at the first 20 lbs of milk, using in this case one pound of a 16% protein meal mixture for each 2 3 lbs of milk produced in excess of the first 20 lbs

In general, mixed farm grains without protein supplement will be satisfactory as supplementary feed to spring pasture and to "aftermath' where meal feeding becomes necessary because of high milk production, or because of shortage of sufficient pasturage Midsummer pasture, on the other hand, or mature or dormant pasturage is approximately the equivalent of timothy hay in protein content and should, therefore, be supplemented with a meal mixture of the sort used during winter feeding It should carry a protein level of 16 or 18%

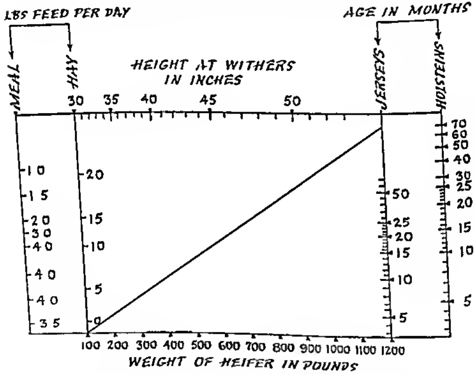
Salt Requirements of Cattle. All cows might well be tested weekly for salt hunger, and extra salt fed if they appear to be hungry for it The usual inclusion of 1% salt in the meal mixture will meet the needs of milking cows that are fed normal quantities of meal mixture However, for cows on pasture and for cows that are fed very limited amounts of meal, extra salt may be required

On the average a 1000 lb dry cow should have 0 75 ounces of

growth, succulent feeds should be decreased and concentrates increased

Fresh and pure *water* should be given to the calf At from 2 to 6 months it can drink from 10 to 15 lbs of water per day in addition to any other liquid such as milk or gruel

CHART AP-A. *Meal and Hay Allowances for Growing Dairy Heifers, Accarding ta Age, Height, or Weight*



Since calves are not able to subsist on roughage until the rumen has developed and become functional, they should not be turned out to *pasture* before they are 4 months old unless arrangements are made to feed them in the same way as though they were penned in the barn Where satisfactory stabling facilities are not available for summer housing the pasture chosen should provide shade and be well-drained

Calf Feeding Schedules. For the first month, the feeding schedule for calves is the same regardless of whether a method using milk, skimmilk, or gruel is used, or whether dry meal feeding system is to be followed. Care should be taken that the calf, within the first 12 hours, obtains the colostrum of its mother. This first milk has special properties essential for the well-being of the calf. Antibodies that protect the calf from diseases in the early stages of its life, and Vitamin A are particularly important components of colostrum.

After the calf is a month old its feeding, with reference to milk or milk substitutes, will depend on the method chosen. Table Ap-2 gives a schedule showing the amounts of the different kinds of feeds which would ordinarily be allowed to calves being raised on the methods, using either skimmilk or calf meal gruel.

TABLE Ap-2 *Showing Quantities of Feeds to Be Allowed per Calf per Day at the Ages Shown and According to the Method of Calf Raising Followed*

Age	Skimmilk method		Other feeds to be used with all of these methods		
	Whole milk lbs.	Skimmilk or gruel lbs.	Dry meal* mixture lbs.	Hay lbs.	Silage or roots lbs.
1 week	6-8				
2 weeks	8-10				
3 weeks	10-12		¼	¼	
4 weeks	12-15		¼ to ½	¼ to ½	
5 weeks	14-18	1-8	½	½	
6 weeks	8-0	8-15	½ to ¾	½ to ¾	
7 weeks		15	¾ to 1	¾ to 1	
8 weeks		15	1	1	
3 months		15	1 to 2	2 to 3	1 to 2
4 months		15	2 to 2½	3 to 4	2 to 4
5 months		15	2½ to 3	4 to 5	4 to 5
6 months		15	3 to 3½	5 to 6	5 to 6

* Use a 16% milking cow ration as the dry meal mixture.

Dry Calf Meal Method of Feeding. This method of calf feeding has much in its favor Its saving in milk and labor, together with freedom from many troublesome digestive upsets often accompanying skimmilk and gruel feeding, make it an attractive plan Nevertheless, the system is not foolproof

Most important is the fact that the success of this system depends in no small measure on the use of a meal mixture designed for this plan of calf raising A mixture that may be acceptable when used with whole or skimmilk may prove entirely unsatisfactory with this plan, and unless feeders are prepared to provide the necessary kind of calf meal they should not consider this scheme of calf raising

This method calls for the use of whole milk for the first month only The amounts to be fed during this period are the same as shown in the calf feeding schedule in Table Ap-2 However, at the beginning of the fifth week the milk is abruptly discontinued This sudden withdrawal of milk has the effect of requiring the calf to satisfy its hunger by eating other feeds that are provided A *gradual* cutting down in the milk allowance on the other hand, frequently results in the calf going partially hungry before it learns to eat the dry food

From the time the calf is a week old a rack of high grade, fine, dust-free hay, together with a continuous supply of fresh water, should be available at all times In addition, a small quantity of calf meal, or better, calf meal pellets may be provided in a feed box to be eaten as desired By the time the milk is cut off the calf will have learned to eat hay and meal, and the removal of the milk will mean only that it will eat more meal

We cannot too strongly urge that a calf meal especially prepared for this method of feeding be employed Milk contains an abundance of riboflavin and of the minerals, calcium and phosphorus, as well as proteins of high feeding value These essentials must be provided in the calf meal if milk is to be replaced at this early age in the development of the calf

Provision for drinking water is also important, and wherever it is possible free access to water is strongly recommended The plan, in fact, is almost one of self-feeding, and calves raised on this system frequently make better progress than where hand feeding is used, not

necessarily because the ration is better, but because it is available when the calf wants it.

A flexible formula for a calf meal suitable for this system of raising calves was discussed in Chapter 18 (see Table 18-5).

Feeding Pregnant Dairy Cows. About two-thirds the weight of the foetal calf is actually made during the last 60 days of pregnancy. This is the usual dry period for the cow, and during this time liberal feed is needed for the calf growth. Otherwise the nutrients required will be taken from the cow's own body reserves, and, as a consequence, her subsequent lactation may suffer. Experiments with cattle show that the gain or loss in body weight by a cow during the last 60 days of pregnancy affects the quantity of milk produced in a lactation. In general, one series of studies found that for each pound of gain in body condition during her dry period, there was an increase during the lactation of:

25 lbs. of milk for Holsteins
20 lbs. of milk for Guernseys
15 lbs. of milk for Jerseys

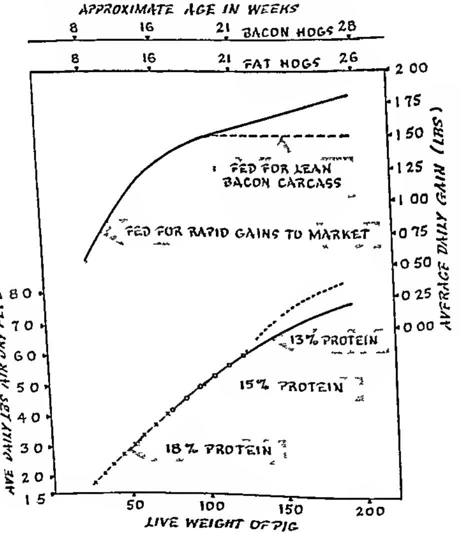
Thus a gain of 50 lbs. in condition may mean from 750 to 1250 lbs. more milk for the next lactation, which in itself is ample justification for attention to the dry cow feeding.

During the dry period the cow should rebuild her reserves of calcium, phosphorus, and protein, which in high producing animals have been partially depleted during the previous lactation. The feeding of farm grains alone to dry cows is not as satisfactory as the use of a ration properly balanced as to minerals and protein during this period. Under most conditions a meal ration carrying 14% of crude protein will be adequate, and while this can be produced by mixing a standard 16% milking cow meal mixture with an equal quantity of farm grains, such practice will not provide adequate mineral supplementation. When such a pratice is followed, add one pound of bone meal and .5 lbs. of salt to each 1000 lbs. of the combination of grain and 16% ration.

Guides to Swine Feeding

The feeding of market hogs is largely a self feeding program, hence, rules for daily allowances are not of primary importance The gain made by self fed market pigs is likely to be related to the TDN

CHART AP-B. *Daily Feed and Daily Gains of Market Pigs, According to Their Attained Weights or Equivalent Ages*



of the ration. When rapid gains are the objective, a mixture of 75% TDN or more is normally fed during the finishing period; whereas the mixture better suited for finishing bacon hogs will carry less than 70% TDN. Of such a mixture, slightly larger amounts will often be eaten, nevertheless, the gains will be slower than those on the normal program. The protein level of the rations to be fed will include an 18%, a 15%, and a 13% during the weaning, growing, and finishing periods respectively.

Some of the relations between the age and weight of pigs and their average feed intake and live weight gains are shown in Chart Ap-B.

Thumb Rules for Feeding the Breeding Herd.

SOWS.

1) In general, feed to dry sows 2 lbs. of meal or its equivalent per day for each 100 lbs. live weight.

2) Pregnant sows require rations fortified with vitamins and minerals. A mineral mixture supplying at least calcium, salt, iron, and iodine should constitute about 3% of the meal ration; and a daily allowance of one-half tablespoonful of a feeding oil to supply Vitamins A and D will be profitable unless these are supplied in some other way.

3) Nursing sows should be fed what they will clean up promptly at three feeds daily. It will range between 10 and 15 lbs. of dry meal per day.

BOARS.

1) A daily allowanee of meal equal to 2% of their live weight.

2) Feed enough to maintain a satisfactory condition of fleshing.

Self-feeding of Brood Sows. Self-feeding of brood sows is entirely feasible if the grain ration is sufficiently bulky to prevent exeessive fattening of the sows. A ration that may be used successfully for the self-feeding of breeding sows consists of a combination of two parts of a normal meal mixture intended for growing market pigs diluted by one part of alfalfa meal or wheat bran. Fresh water may be eon-

veniently supplied by an ordinary pressure water bowl of the type used in dairy stables

Factors Affecting the Excellence of Hog Carcasses Intended for Bacon.

1) The greatest single factor causing an undesirable bacon carcass is excessive fat

2) Male pigs normally yield fatter carcasses than females at equal marketing weight

3) Pigs that have been fed heavily on wheat or corn during the last two months of feeding yield carcasses, within bacon weights that are usually overfat

4) Level of protein in the hog ration has no direct effect on carcass excellence, though it does affect the growth of the pig

5) Restriction of rate of gain of pigs after a live weight of 125 lbs tends to result in a leaner carcass This is easily accomplished by using a lighter, bulkier fattening ration

To produce the greatest number of "bonused' carcasses, feed young pigs liberally on a properly balanced low fiber ration to about 125 lbs Then change to a lighter ration for finishing After pigs weigh 100 lbs, daily gains of 1 5 lbs are rapid enough Faster gains than this are correlated with overfat carcasses

As an example of this feeding practice, the following rations for the *growing* and *fattening* periods are given

Feeds	Growing pigs (to 125 lbs)	Fattening pigs (125 lbs to market)
Barley (or comparable basal feed)	90 lbs	75 lbs
Wheat bran	0	20
Protein mineral supplement	10	5

In this plan the wheat bran may be replaced by alfalfa meal, or barley and bran may be replaced by 95 lbs of oats Note that oats are not used in the growing ration, but barley here may be replaced in part by wheat, or corn, or No 1 Feed screenings

Horse Feeding

Horse feeding as such has not been considered in any previous chapters in this book. One of the reasons is that meal mixtures for this class of stock are seldom compounded with the help of feeding standards. Adult work stock are adequately fed by a combination of oats (or its equivalent), non-legume hay, and salt; and breeders usually require only iodine in addition to this ration. We do not mean that meal mixtures cannot be used. In fact horses do very well on any standard dairy meal mixture, which is more acceptable if pelleted or crumbled to overcome the fine powdery condition of ground feed.

Thumb Rules. The problems of horse feeding therefore are more in the matter of quantities to be fed than in makeup of meal mixture. In most cases maintenance of body weight is a better guide in this respect than a formal feeding standard. Horses often seem to differ in their requirements more than cattle do, as is evident in the different quantities of feed needed by team mates to maintain steady body weight. Feeding standards, therefore, are no more than guides, and thumb rules may be as practically accurate as is needed. One set of such rules is as follows: (1) Of roughage feed from 1 to 1½ lbs. per 100 lbs. live weight daily. (2) Of grain feed from 1 to 1½ lbs. per 100 lbs. live weight daily. (The smaller allowance of roughage and the larger one of grain for horses at heavy work, and vice versa for those doing light work.)

Idle days. One of the problems of work horse feeding arises when idle days occur. On such days feeding must be reduced to avoid such a condition as azoturea. The practical solution is to feed a bulky low energy ration on the night before an idle day. This satisfies the appetite without the unwanted heavy energy intake at this time. A bran mash is made as follows:

To a quantity of dry wheat bran about equal by measure to the usual feed of grain, add a teaspoonful of salt and enough hot water to make a stiff mash. Cover and allow to steam. Feed when cool. If

desired a cupful of molasses may be added to the bran before steaming

Feeding Orphan Foals. Occasionally the horseman will have to raise an orphan foal General directions that may be helpful are given below

To feed an orphan foal, secure milk from a fresh cow, preferably a low tester To a pint of the cow's milk add ¼ pint of lime water and a teaspoonful of sugar This will make enough for two feedings at first

Another formula that has been successfully used consists of

Dried whole cow's milk	40%	3 lbs
Dried skimmilk	30%	
Sugar	30%	
Limewater	8 oz	(1 cupful)
Water	5 lbs	(2 Imperial quarts)

Feed the orphan foal daily about 4 quarts of milk or of the above fluid per each 100 lbs of his live weight Give in addition 1 tablespoonful of cod liver oil per day

Warm the fluid to about 100°F and feed from a nursing bottle

For the first few days feed every hour using about half a pint of the prepared cow's milk at each feeding Gradually lengthen the time between feedings and increase the allowance of milk Care must be taken, especially during the first two weeks not to overfeed the foal, or scours will result

Teach foals to drink from a pail as soon as possible so that the bottle feeding may be discontinued, thus eliminating the problem of sterilizing bottles and nipples

If a little grain is put into the bottom of the pail of milk the foal soon learns to eat solid food Once this occurs feed a little grain three times a day

Get the orphans on good pasture as soon as possible but continue to provide a little grain and hay

As a grain mixture the following has given good results

125 lbs ground oats
100 lbs wheat bran
25 lbs linseed oilmeal

Good, bright clover hay, free from dust is to be preferred to timothy hay for foals. Good timothy, however, is far better than poor quality clover.

Schedule of Feeding Orphan Foals

Age	Feed	Amount per feed	Times per day to feed
1 week	Cow's milk—1 pint Lime water—3 tablespoonfuls Sugar—1 teaspoonful	¼ to ½ pint	Every hour
2 weeks	As above	½ to 1 pint	6 times
3 to 5 weeks	As above but omit the sugar	1 pint or more according to appetite and size of foal	6 times
5 to 8 weeks	Gradually substitute skim for whole milk Omit the lime water	As per appetite	4 times
8 to 12 weeks	Skim milk *plus* small grain allowance	As per appetite	3 times

The Proximate Analysis as an Index of Feeding Value For Meal Mixtures Whose Formulae Are Unknown

The marked increase in the use of commercially prepared feed mixtures, whether they be complete ready-to-feed combinations or mixed supplements, has presented the problem of judging which one among the many available represents the preferred choice. With few exceptions little information is given to the feeder concerning such mixtures, other than the list of ingredients claimed to be present and the guarantee of minimum protein, minimum crude fat, and maximum

crude fiber content In the case of mineral supplements, and also in certain special types of mixtures, additional and sometimes alternate items are required to be guaranteed, as for example, the salt content or maximum fluorine content, etc In most cases, however, the mixtures will furnish protein and energy, and, consequently, will carry guarantees of protein, fat, and fiber, and it is on the basis of the figures for these three components that the feeder usually attempts to judge the quality and usefulness of the mixture Unfortunately, figures for protein, fat, and fiber are not of much use as indices of quality of such products, and feeding value cannot be so simply indicated

For example, if the leaves of early cut timothy hay are dried and ground, and compared to a sample of dried, ground feces produced by an herbivorous animal that has subsisted entirely on such feed, these two products cannot be distinguished except by the use of a strong magnifier The analysis of one such case is shown in the figures below

	Ground timothy leaves	Feces from these leaves
Crude protein	7 9%	8 2%
Crude fat (E extract)	1 3	2 4
Crude fiber	34 7	24 8
Nitrogen free extract	50 9	59 2

Based on this chemical information one might erroneously judge that the feces have the higher feeding value

Or, again, one might note that ground shoe leather is a high protein, low fiber product of animal origin, but of no feeding value Weed seeds carry as much and often more protein and sometimes less fiber than cereal grains (see Table Ap-3)

Furthermore, we should not forget that many rations can be improved for some special purposes by *increasing* the fiber content

In other words, where rations are compared in usefulness, the one with the higher protein or the lower fiber may not be the choice It will depend upon what the ration is wanted for, what feedstuffs were used, and the content of essential nutrients These items are not indicated by either crude protein or crude fiber

TABLE Ap-3 *Proximate Analysis of a Few Weed Seeds*

Plant seed	Water	Protein	Fat	Fiber	N-free extract	Ash
	%	%	%	%	%	%
Pigweed seed	9	19	7	11	50	4
Lambs-quarters	10	15	5	20	46	4
Black bindweed	11	10	2	7	69	1
Wild radish seed	8	24	25	10	22	11
False flax	9	22	30	11	22	6

The Tag on the Bag. The list of ingredients on the tag of the commercially prepared feed and the integrity of the feed dealer (or manufacturer) are of much greater importance in indicating the usefulness of a mixed ration than are the figures for protein, fat and fiber. Perhaps it may not be out of place to note that no reputable feed manufacturer or feed dealer will knowingly offer for sale or recommend in a particular case, a feed mixture that will not give satisfactory results when used as recommended. His business obviously depends on his continuing to sell to the same customers.

Are "Balanced" Rations Necessary?

All modern testbooks of feeding advocate the use of "balanced" rations. The reasons for their use are not always so prominently set down, and often the reasons advanced are not wholly sound from the standpoint of economical feeding. Actually few humans, let alone animals, consume perfect rations. What then is the justification for the general advice to feed balanced rations to farm animals? The reason may be found in the definition—"A *balanced ration* is one in which the food requirements of the particular animal are completely met without excess of any nutrient."

The various nutrients required by an animal are numerous and include not only the protein, fat, and carbohydrate of the older balanced ration, but as well a long list of minerals and vitamins. A few of these nutrients are interchangeable, completely or partially; but

most of them are required in specific amounts as well as in definite proportions to other nutrients In general, natural foodstuffs contain most of the nutrients needed by animals, but they are unbalanced as to quantities By mixing together foodstuffs of different nutrient composition, we can provide rations more nearly balanced to the needs of the animal than we can with single feedstuffs

For example, let us suppose that a particular animal requires for its best growth or production 1 5 lbs of protein and 8 lbs of TDN If some feed, such as corn, contains 10% of protein and 80% of TDN, then 10 lbs of corn would provide this animal with exactly the amounts of TDN needed, but only one pound of protein would be provided This shortage would limit full growth rate or production

To get the extra half pound of protein needed, we can do one of two things Increasing the quantity of corn to 15 lbs would provide the 1 5 lbs of protein, but would also furnish 12 lbs of carbohydrate, or a surplus of 4 lbs This surplus could not be used and accordingly would be burned as a means of getting rid of it

Alternately the balance of the corn ration (as to protein and carbohydrate only) could be changed by mixing one pound of soybean oilmeal with 6 5 parts of corn The resulting combination would contain 15% protein and 80% TDN, and 10 lbs of it would provide 1 5 lbs of protein and 8 lbs of TDN needed

Thus we add a protein supplement to basal feeds, not becasue the basal feeds contain no protein, but because a greater proportion of protein to TDN than is found in such feeds will better meet the animals requirements in that respect

The Economics of Balancing the Ration. What are the economics of such a balancing of a ration? In our example evidently 8 66 lbs of corn plus 1 34 lbs of soybean oilmeal have provided the 1 5 lbs of protein needed by the animal To provide the necessary protein with corn would have required 15 lbs of the corn Thus, 1 34 lbs of oilmeal saved 6 34 lbs of corn, or one pound of oilmeal was worth about 4 7 lbs of corn Providing that the corn thus saved could be used to feed more animals, or put to some other equally profitable

use, then if soybean oilmeal could be bought for just 4.7 times the cost of corn, it would be immaterial whether the balanced ration were used or not (assuming for the sake of this example that no other factors were involved). If oilmeal costs more than this, using the balanced ration would be uneconomical. If, however, oilmeal could be bought for less than 4.7 times the price of corn, then balancing the ration would pay.

This principal applies to every nutrient of the ration; for the efficiency of the ration is dependent upon tbe extent to which it provides without waste the operating needs of the animals fed. Thus it may be that salt, calcium, or Vitamin A may need to be increased in the ration to balance it properly. The perfectly balanced ration is always the most efficient ration, because it is the one of which the smallest quantity will be required to meet the food needs of the animal.

Evidently, then, we cannot say without qualification that it will necessarily pay to feed a balanced ration. If protein supplements are too costly in relation to basal feeds, it may not pay to completely balance the ration as to protein level. We do not mean by this statement that the total intake of protein may be reduced without penalty, rather we mean that it may pay better to feed extra amounts of lower protein mixtures than to use the normal quantities of a balanced ration. Protein, however, is but one part of the ration and one which may vary over relatively wide ranges with no perceptible effect on the health of the animal. Unfortunately, this is not true with minerals and vitamins. With these nutrients it is not a matter only of efficient rations in terms of maximum production; it is often a matter of the ability of the animal to produce or reproduce at all, if, indeed, it does not determine its ability to live. There can be no question therefore of the importance of "balance" in the ration in regard to the so-called protective nutrients. The greater the use of by-products, the greater the possibility that special supplementary sources of some nutrients will be required; since in the processing of natural feeds losses and changes in the composition of the original material take place, and rations prepared by by-products become less well-balanced to the operating needs of the body.

The Misuse of Balanced Rations. In recent years there has been a marked increase in the number of farmers who have employed commercially mixed balanced rations in the feeding of livestock. However, these farmers have frequently diluted the purchased mixture with home-grown grains, either by deliberately mixing or by alternating the feeding of one with the other. This practice sometimes leads to difficulties.

For example, a 16% protein dairy meal mixture diluted 1:1 with oats carries 14% of protein, and whereas the 16% balanced ration normally would have about 2% of bone meal in it, the oats–16% combination will have only half this quantity of mineral supplement. Thus when a balanced ration is used as but a part of the non-roughage feed, the protective nutrients may have been diluted in amount so that the ultimate combination fed is inadequate nutritionally for the needs of the animals. If a commercial mixture is to be fed in combination with farm grains, a concentrate or supplement mixture should be chosen rather than a ready-to feed balanced ration. The former is intentionally more heavily fortified with minerals and vitamins to cover the deficiency of the farm feeds that are to be fed with it.

Feeding Iodine

Fortification of the rations of pregnant females with iodine is indicated in all so-called "goitrous regions." The source of the iodine is largely immaterial. It is desirable, if inorganic sources are to be used (potassium iodide or sodium iodide), to insist on a stabilized material, since the iodine in unstabilized, iodized salts will sublime and disappear when exposed to the air. There is so little danger from iodine poisoning that it may be disregarded in practical feeding.

The minimum quantities of iodine that should be provided to pregnant females have not been acceptably established. We should note, however, that salt carrying 0.05% of potassium iodide has been effective in preventing clinical evidence of iodine deficiency. On this basis the following average daily intakes of potassium iodide appear to have been adequate:

Mares and cows	25 mgs. per day
Sows and ewes	15 mgs. per day

Iodine may be incorporated in the feed or some part of it, as in the mineral mixture. Or it may be given to the animals individually with their feed or water.

When iodine is to be fed to the animals directly, the allowances are conveniently measured if the iodide is dissolved in water. For all

TABLE Ap-4 *Annual Requirements of Meal for Livestock*

Class of animal	Special conditions	Amounts of concentrates per head
Cattle		
Cows in milk[1]	4,000 lbs. milk	1000 lbs.
	6,000 lbs. milk	1800 lbs.
	8,000 lbs. milk	2400 lbs.
	10,000 lbs. milk	2800 lbs.
Breeding bulls		1000 lbs.
Young stock over 6 months		500 lbs.
Calves under 6 months		450 lbs.
Fattening cattle	per 100 lbs. gain	300 lbs.
Horses		
Work animals	1,400 lbs. weight[2]	2500 lbs.
Young stock over 1 year and stock at light work		1000 lbs.
Sheep		
Breeding flock		200 lbs.
Fattening stock	90 days feeding	100 lbs.
Swine		
Sows	2 litters per year	2000 lbs.[3]
	1 litter per year	1500 lbs.[3]
Breeding boars		1000 lbs.[3]
Market pigs	Weaning to 100 lbs. weight	250 lbs.[3]
	100 lbs. to 200 lbs. weight	400 lbs.[3]

[1] For spring calvers reduce these amounts 25%.
[2] For heavier animals increase amounts 200 lbs. for each 100 lbs. increased weight.
[3] Total meal or its equivalent.

classes of farm animals dissolve 1 5 grams potassium iodide in 1 liter of water, and give daily to each pregnant female 1 tablespoonful of the solution

The solution may be given daily or a solution made seven times as strong may be used and a tablespoonful administered once a week For beef cows having a common drinking trough, add to the water in the trough enough of the iodine solution for the whole herd

Annual Requirements of Meal for Livestock

Feeders frequently require to estimate the quantities of grain or meal mixtures on the average to feed different classes of livestock for some specified period of time Table Ap-4 has been prepared to meet average conditions

APPENDIX 2

Feedstuffs Control and Legislation

IN CANADA and in most of the United States, feeds passing through commercial channels are subject to registration and to some measure of legal regulation. Such regulation is for the protection of the consumers and the manufacturers alike. With respect to the consumer it is intended to insure that the product offered is properly labeled (in its broad sense) and that it is wholesome as a food for his livestock. For the honest manufacturer it is an attempt to protect him from practices of unscrupulous competitors who misrepresent their products to the potential consumer.

Canadian Legislation

In Canada, feeding stuffs control is vested in a branch of the Federal Department of Agriculture with the Canada *Feeding Stuffs Act* the enabling legislation.

Canadian feed legislation did not suddenly appear full-blown. Rather, it developed step by step in response to changing conditions of the industry. In many instances specific sections of the *Act* were incorporated at the request of the feed manufacturers themselves, and the more recent modifications were presented to the feed trade for study and suggestion before official adoption. With the increasing use of commercially mixed rations the importance of the *Feeding Stuffs Act* as a guide has also increased, and this has naturally been paralleled by an increased interest in the legislation both by the trade

and by the feeder It seems appropriate, therefore, to include in a text of this nature a brief discussion of the background of feed control and of typical present day feed legislation Since pertinent information is not available elsewhere in as precise form we shall use as an example the situation in Canada In general principles and philosophy it will not be unlike that in force elsewhere in America

The Canadian *Act* originated as a consequence of the development of the commerce of feeding stuffs, which brought about problems of weed seed distribution The seriousness of this problem was evident from an investigation of the weed seed content of the feedstuffs that were being shipped from the grain growing areas and from flour milling centers to the livestock farms, a study which revealed a situation indicated by the figures in Table Ap-5

TABLE Ap-5 *Weed Seeds in Commercial Feeding Stuffs*

Feed	Whole weed seeds per pound		
	Maximum	Minimum	Average
Bran shorts middlings	4704	0	246
Crushed grain	2248	8	677
Meals (various)	18768	16	1802
Feed grain (unground)	8888	908	4022

The weed seeds included those from about 50 species of plants troublesome on barren lands, and their hidden presence in ground feeds was becoming a menace, introducing noxious weeds on farms previously free of them The situation resulted in amendments to the *Adulteration Act* requiring that bran, shorts, middlings, and chop feeds be free of vital seeds of any noxious weeds defined under the *Seed Control Act*

Investigations revealed that much of the weed seed problem arose from the disposition of screenings cleaned from western grown grains at terminal elevators at the head of the Great Lakes Elevator screenings have potential feeding value, since they include broken and shrunken wheat, wild buckwheat, wild oats, and some other cultivated coarse grains Screenings, however, were foul with fine weed

seeds, such as lambs quarter, stinkweed, mustards, etc., some of which are injurious to livestock. Equipment for the removal of these weed seeds was not generally available at the time.

These investigations revealed another problem. Microscopic examinations revealed that finely ground oat hulls were being added to shorts. This addition resulted in a lighter colored and more floury product and led farmers to believe they were getting a better quality feed.

The most common adulteration and the one most often complained about, was the addition to mill feeds of ground grain screenings. This was, in effect, returning to the bran and shorts the screenings cleaned out of the wheat before the flour was milled. Had this practice not included the harmful weed seeds it might not have given rise to so much complaint. The petitions from farmers individually and through their livestock organizations led to new legislation in 1920 to regulate the sale and inspection of feeding stuffs. This Canada *Feeding Stuffs Act* of 1920 was designed to make it possible for feeders to know what they were buying and at the same time to protect manufacturers and dealers from unscrupulous competition. Certain materials including hays and straws and the common whole grains as well as roots, wet brewers' grains and other watery materials, which are often of a perishable nature, were exempted from the provisions of the law. The materials that are covered are classified into three main groups, vis.: chop feeds, flour mills by-products, and commercial feeding stuffs. These each have different standards of quality and demand different labeling; but all carry a uniform restriction against the presence of mustards, purple cockle, ergotized grains, and other seeds or materials regarded as injurious to the health of livestock or poultry.

The large number and great variety of materials that enter into the composition of mixed feeds makes it impossible to judge quality from simple inspection. The 1920 law required every bag (or parcel) of such feeds to be labeled by the manufacturer with the minimum percentage of protein, and maximum percentage of fat and crude fiber as well as the specific name of every ingredient contained in the feed. (This provision has been extended in some respects in the later re-

vision) The administration of the last part of this requirement made it necessary to establish official names and definitions of feeding stuffs involved, and this part of the *Act* has proved to be a most useful one to all who have occasion to use feeds

The 1920 version of the *Act* has been modified as new developments in livestock feeding and in grain handling and processing have dictated, but the basic function of the legislation has remained the same Some idea of the scope of the Canada *Feeding Stuffs Act* as well as the specific kind of problem dealt with are indicated by the excerpts from the 1953 revision which follow To anyone seriously concerned with the nature of feeds and their use it is worthwhile reading The fact that as legislation it applies only to Canada is quite immaterial in this respect For those who are concerned with commercial feeds professionally, the laws applying to their own problems must, of course, be used

Excerpts from

The Feeding Stuffs Act (Chapter 113 of the Revised Statutes of 1952) and Regulations

CANADA DEPARTMENT OF AGRICULTURE

(*c*) Feeding stuff means any article intended for consumption by live stock and purporting to supply proteins, carbohydrates fats minerals condiments or vitamins and shall include any article prepared for the purpose of preventing or correcting nutritional disorders

(1) Subject to subsection (2) this Act does not apply to

(*a*) whole hays straws corn stover and silage when unmixed with any other material

(*b*) hulled oats hulled barley cracked Indian corn and the whole seeds or grains of cultivated farm crops

(*c*) feeding stuff prepared in accordance with a prescription provided and signed by the purchaser for consumption or processing by such purchaser

(*d*) feeding stuff for export from Canada and so labelled or

(*e*) feeding stuffs sold by the individual grower thereof

(6) The Minister may refuse to register any feeding stuff
(*a*) if in his opinion the brand or name would tend to deceive or mislead a purchaser in respect of the composition or utility value of the feeding stuff,
(*b*) under a brand or name identical with or in the opinion of the Minister likely to be confused with a brand or name already applied to a registered feeding stuff,
(*c*) if the specific name of each and every ingredient used in its manufacture be not stated, or
(*d*) if a sample of the feeding stuff, which, upon request, the applicant shall submit and certify as representative of the feeding stuff to be registered, is found not to accord with the provisions of this Act or the regulations

(7) No change in the brand, name, chemical composition or ingredients of a registered feeding stuff shall be made without the written approval of the Minister, who may refuse to allow any change that in his opinion would lower the feeding value of such feeding stuff but may authorize, either at the time of registration or subsequently, such variations as in his opinion do not warrant registration as a separate and distinct article

5 (1) Every package containing any feeding stuff mentioned in column 1 of Schedule A shall be labelled in such manner as may from time to time by regulation be prescribed

(2) Every such label shall, in relation to such feeding stuff, show conspicuously and legibly
(*a*) the name and address of the registered owner,
(*b*) the brand and name, which shall include such particulars of the composition and nutritive purposes as may be prescribed,
(*c*) the registration number,
(*d*) the net weight of contents,
(*e*) the specific name of each ingredient, employing such terms, and giving such particulars of the character, quality and quantity of any ingredient, as may be prescribed,
(*f*) the guaranteed analysis setting forth such particulars as are mentioned in column 2 of such Schedule, and
(*g*) any matter mentioned in this subsection that is also required to be set forth upon application for registration corresponding as set forth upon the label in every particular with that so set forth upon application

The Feeding Stuffs (General) Regulations

6 (1) Except as provided in subsection (2), or as the Minister may authorize in any specific case, every package of feeding stuff suitable for packaging in containers made of burlap jute, cotton or paper, sold or offered or held in possession for sale in Canada, shall contain a net

Schedule A

COLUMN 1	COLUMN 2
Article of Feeding Stuff	Particulars of analysis to be guaranteed in accordance with Section 5 (2) (*f*)
	Amounts to be stated as percentages of the weight of the article, provided that iodine may be stated as ounces per hundred pounds of the article
Feeding stuffs (excluding chop feeds) ground crushed or in meal cake pellet or biscuit form not otherwise provided for and to which in the opinion of the Minister the particulars specified are appropriate	Minimum amount of crude protein Minimum amount of crude fat Maximum amount of crude fiber
Mixed feeding stuffs commonly called supplemental feeds purported to supply both proteins and minerals in excess of the amounts required in complete or balanced meal mixtures	Minimum amount of crude protein Minimum amount of crude fat Maximum amount of crude fat if in excess of 7 per cent Maximum amount of crude fiber Actual amounts (within permitted tolerances) of such of the following as are intentionally or purportedly present Calcium (Ca) Phosphorus (P), Iodine (I), Iron (Fe) and Salt (NaCl)
Mixed feeding stuffs for mineral nutrition	Actual amounts (within permitted tolerances) of such of the following as are intentionally or purportedly present Calcium (Ca) Phosphorus (P), Iodine (I), Iron (Fe) and Salt (NaCl)
Blood meal	Minimum amount of crude protein
Bone meal or any other bone product except bone char	Minimum amount of crude protein Maximum amount of crude fat if in excess of 5 per cent Actual amounts (within permitted tolerance) of phosphorus (P) and calcium (Ca)
Dried milk or buttermilk	Minimum amount of crude protein
Dried whey	Minimum amount of crude protein Minimum amount of lactose
Fish liver meal	Minimum amount of crude protein Minimum and maximum amounts of crude fat
Fish meal or any other product (except liver meal) of fish or fish waste	Minimum amount of crude protein Maximum amount of crude fat Maximum amount of crude fiber if in excess of 2 per cent Maximum amount of salt (NaCl)
Meat meal or scrap, tankage or any other product of meat or meat and bone including whale meat	Minimum amount of crude protein Maximum amount of crude fat Maximum amount of crude fiber if in excess of 2 per cent
Semi solid milk or buttermilk	Minimum amount of crude protein Maximum amount of moisture

quantity of five pounds, ten pounds, twenty-five pouods, fifty pouods or one hundred pounds of such *feeding sluff*

(2) Nothing in subsection (1) shall be deemed to prohibit

(*a*) the use of any bag or container by a farmer for containing his own produce for sale or processing,

(*b*) the use of any bag or container by a retailer selling in bulk and not as a unit any quantity of feeding stuff specified by a customer,

(*c*) the use of any cootainer for shipment of ingredients for feeding stuffs to a manufacturer of feeding stuffs where the product is not to be resold io such container,

(*d*) the packaging of tonics or conditioners io packages contaioing a net quantity of less than five pounds,

(e) the packaging of rolled or crimped unhulled oats or of oyster shell, clam shell or coquina shell or of aoy feediog material purported or commonly coosidered to be primarily a source of calcium or calcium and grit in packages containing a net quantity of eighty pounds, or

(*f*) tbe packagiog of feed flour in packages containiog a net quaotity of ninety-eigbt pounds

9 (1) For the purposes of this section,

(*a*) 'mineral feed' means a mixed feeding stuff that supplies minerals for tbe nutrition of livestock but does not include

(i) feeding stuffs intended or represented primarily as complete or balanced mixed feeds or as protein mioeral or protein-mineral vitamin supplemeots and which are required to be registered, pursuant to seciton 4 of the Act,

(ii) salt to which has been added one or more of the following, namely, a cobalt compound, a manganese compound, an iodine compound, a recognized iodine stabilizer and coloring matter, which coloring matter may be an iron compound,

(iii) any single ingredient feed to which has been added one or more of the following, namely a cobalt compound, an iodine compound a recognized iodine stabilizer and colouring matter, which colouring matter may be an iron compound or

(iv) any preparations for the treatment of disease or to aid recovery from disease or debility which preparation is represented for use only while such disease or debility persists and any other preparation represented for temporary use for specified purposes which preparation, in the opinion of the Dominion Animal Pathologist, would usefully serve such purposes when used to supplement a balanced ration,

(*b*) "trace mineral feed' means a mixed mineral feed that is intended or represented as supplying mineral elements other than calcium, phosphorus and salt and which is labelled with the percentage content of such of the following as are purportedly present iodine (I), iron (Fe), cobalt (Co), manganese (Mn) and copper (Cu)

(2) Every mineral feed shall contain only ingredients incorporated to supply calcium (Ca), phosphorus (P), salt (NaCl), iodine (I), iron (Fe), copper (Cu), manganese (Mn) or cobalt (Co), provided that

(*a*) a mineral feed containing iodine may contain a recognized iodine stabilizer,

(*b*) a mineral feed which is in block form may contain a binding agent of a kind and in a quantity acceptable to the Minister,

(*c*) a trace mineral feed may contain a carrier of a kind and in a quantity acceptable to the Minister but for which no chemical claims shall be made

(*d*) any mineral feed may contain a dust control agent of a kind and in a quantity acceptable to the Minister

(3) In the application for registration and on the package label the purpose of any ingredient incorporated into a mineral feed as a binding agent or a carrier or a dust control agent shall be clearly indicated

(4) Apart from the statement of analysis and ingredients required by the Act no representations shall be made on the package label as to the value or need of mineral elements other than

(*a*) a calcium, phosphorus salt, iodine and cobalt in a mineral feed for cattle, sheep or horses,

(*b*) calcium, phosphorus, salt, iodine, iron and copper in a mineral feed for swine, or

(*c*) calcium, phosphorus, salt, iodine and manganese in a mineral feed for poultry

(5) Every mineral feed intended or represented for feeding to cattle, sheep, horses or swine, other than a trace mineral feed, shall be eligible for registration only if it conforms to the specifications of Table 2 of the Schedule hereto, provided that

(*a*) nothing herein contained shall require the use of salt in any mineral feed,

(*b*) for each one per cent that the phosphorus content in a mineral feed for cattle, sheep or horses exceeds the minimum specified, the calcium content may be decreased by not more than one per cent,

(*c*) such specifications shall not apply to a mineral feed for cattle, sheep or horses which is in block form and which contains a minimum of 4 5 per cent by weight of phosphorus

(6) In the application for registration and on the package label the names of the kinds of livestock for which such mineral feed is intended shall be clearly indicated

(7) Every mineral feed intended or represented for feeding to poultry, foxes rabbits or mink which contains more than one ingredient shall be eligible for registration only if it is a trace mineral feed but a trace mineral feed may be represented for feeding to any kind of livestock

(8) Every package of trace mineral feed shall be labelled with mixing directions which prescribe its use at not more than five pounds per ton

in complete or ready to feed mixtures and not more than twenty pounds per ton in feed supplements containing 24 per cent or more of crude protein.

10. Every drum or package of any product purported or commonly considered to be primarily a Vitamin A or Vitamin D or both Vitamin A and Vitamin D supplement, sold or offered or held in possession for sale in Canada as feeding stuff, other than fish oils to be further processed or blended before use as, or for incorporation into, feeding stuffs, shall be labelled with the following particulars:

(*a*) the name and principal address of the manufacturer, importer or seller possessing or assuming proprietorial rights to such product;

(*b*) the brand name, if any;

(*c*) the maximum percentage of free fatty acid expressed as oleic acid if in excess of two per cent at the time of distribution from the premises of the proprietor or his agent;

(*d*) the specific name of every ingredient incorporated for its Vitamin A and Vitamin D content, and also of other ingredients, if any, as the Minister may direct, except that

Tolerances for Minerals

Applicable to Feeds for which mineral guarantees are required in Schedule A to the Act

Mineral Item	Guaranteed Amount (as per cent by weight of the feed)	Permitted Tolerance not to exceed
Calcium (Ca), Phosphorus (P), and Salt (NaCl)	Under 3 per cent	A deficiency or excess of 0 5 per cent of the feed
	3 per cent to 15 per cent inclusive	Subject to Notes 1 and 2, a deficiency or excess of 20 per cent of the guaranteed amount
	Over 15 per cent	Subject to Notes 1 and 2, a deficiency or excess of 3 0 per cent of the feed
Iodine (I), Iron (Fe), Cobalt (Co), Manganese (Mn), and Copper (Cu)	All amounts	A deficiency of 20 per cent of the guaranteed amount, an excess limited to quantities likely to be injurious to the health of livestock

NOTE 1—In a mineral feed for swine, the minimum percentage of calcium (Ca) shall not be less than 5 times the percentage of phosphorus

NOTE 2—In a mineral feed for cattle, sheep or horses, the maximum percentage of calcium (Ca) shall not exceed 2½ times the percentage of phosphorus (P).

(i) the name 'blended fish oil" may be employed to designate a blend of oils from two or more kinds of fish, and

(ii) the name 'cod liver oil' may be applied to oil from the livers of the cod family, including cod, haddock, hake, cusk and pollock, or

(e) in lieu of the particulars specified in paragraph (d), a general nutritive designation acceptable to the Minister such as "Vitamin A and D Feeding Oil," or "Vitamin A and D Supplement," subject to the following provisions

(i) such designation may be applied only to a product of guaranteed vitamin potency containing per gram at least 85 international units (I U) of Vitamin D and 850 international units (I U) of Vitamin A, when the said vitamins, respectively, are indicated or implied, and

(ii) the term "fortified' or other term of like purport shall not be applied to a fish oil which constitutes less than 75 per cent by weight of a named kind, nor to a product containing per gram less than 150 international units (I U) of Vitamin D and 1,000 international units (I U) of Vitamin A, when the said vitamins, respectively, are indicated or implied,

(f) in the case of a product guaranteed as to Vitamin A or Vitamin D potency

(i) such potency expressed as a minimum number per gram of

Table 2

Specifications for Mineral Feeds under Section 9(3) (*a*) of these Regulations

Mineral Item	Content or Proportion in Mineral Feeds for Feeding to	
	Swine	Cattle and/or Sheep and/or Horses
Minimum calcium (Ca) content—		
(*a*) in mixtures containing salt	22 5%	15 0%
(*b*) in mixtures containing no salt	30 0%	22 5%
Minimum phosphorus (P) content		
(*a*) in mixtures containing salt	nil	6 0%
(*b*) in mixtures containing no salt	nil	9 0%
Maximum proportion by weight of calcium (Ca) to phosphorus (P)	nil	2 5 to 1
Minimum proportion by weight of calcium (Ca) to phosphorus (P)	5 to 1	nil
Maximum salt (NaCl) content in mixtures containing salt	25 0%	33 0%
Minimum salt (NaCl) content in mixtures containing salt	20 0%	25 0%

international units (I U.) provided that for any product not specifically designated for mammalian use only, the method of assay for Vitamin D shall be the chick assay method of either the Association of Official Agricultural Chemists (A O A C) or the British Standards Institute (B S I), and

(ii) the laboratory control number and the month and year of guarantee,

(g) in the case of a product not guaranteed as to Vitamin A or Vitamin D potency

(i) the word "untested," or if the product is a recognized source of both Vitamins A and D but tested for one only of the said vitamins, the words "untested for Vitamin A" or "untested for Vitamin D," as the case may be, such word or words to appear conspicuously in immediate association with the brand or name of the product, and

(ii) the month and year in which the drum or package was filled

The Feeding Stuffs (Ministerial) Regulations

(2) Where a feeding stuff contains one ingredient only, the name of the feeding stuff, other than the brand name, if any, shall be the name of that ingredient

7 Where protein feeds identical as to kind are to be guaranteed by any manufacturer to contain different percentages of protein they are not eligible for registration unless the application for registration sets out

(a) a different brand name for each protein level, or

(b) the percentage of protein content as part of the brand or name

8 (1) Where a mixed feeding stuff is represented as supplying protein or carbohydrates it is not eligible for registration unless

(a) the application for registration indicates in the name of the feeding stuff or in direct association therewith

(i) the class of livestock for which it is intended, or

(ii) a general nutritive classification of the feeding stuff, (e g protein supplement, basal feed or roughage feed); and

(b) the feeding stuff possesses the essentials in chemical and physical composition for the purpose or purposes indicated

(2) Unless the applicant establishes that there are special circumstances to warrant registration, a mixed feeding stuff is not eligible for registration

(a) as a protein supplement, if it contains less than thirty per cent by weight of crude protein,

(b) as a basal feed, if it contains more than eighteen per cent by weight of crude fiber, or

(c) otherwise than as a roughage feed, if it contains more than eighteen per cent by weight of crude fiber.

General

12 (1) Except as provided in subsection (2), a feeding stuff that supplies or that is purported to supply protein, carbohydrates, fats or minerals shall not contain

(*a*) more than one half of one per cent by weight of any or all of the materials listed in Table 2 of the Schedule hereto, but when screenings are sold or offered for sale singly they may contain not more than one per cent by weight of such materials and an additional one per cent by weight of wild mustard and hare's car mustard seeds

(*b*) fluorine (F) in an amount likely to be deleterious to livestock and not exceeding the following proportions

(i) 0 2 per cent by weight (2,000 parts per million) in any mineral which is represented for feeding direct to cattle or in any mineral mixture for cattle containing up to 9 per cent by weight of phosphorus

(ii) 0 3 per cent by weight (3 000 parts per million) in any mineral mixture for cattle containing at least 9 per cent by weight of phosphorus,

(iii) 0 027 per cent by weight (270 parts per million) in any protein mineral supplement for cattle containing 24 per cent or more but not more than 30 per cent by weight of protein,

(iv) 0 036 per cent by weight (360 parts per million) in any protein mineral supplement for cattle containing more than 30 per cent by weight of protein, and

(v) in any other feeding stuff containing less than 24 per cent by weight of protein

0 010 per cent by weight (100 parts per billion) for sheep,
0 009 per cent by weight (90 parts per million) for cattle,
0 014 per cent by weight (140 parts per million) for swine,
0 035 per cent by weight (350 parts per million) for poultry

(*c*) damage from heat must mould or any other cause which would

(i) render it unfit for feed or

(ii) make it unsafe for feeding in proportions commonly used, unless the feeding stuff is sold under such conditions as the Chief of the Plant Products Division may authorize in any particular case

(*d*) any product of animal bird or fish origin that is not fresh or sound or that has not been cooked thoroughly at not less than boiling temperature

(*e*) any hoof, horn or hair of animals or feathers except in such amounts as are reasonably unavoidable in good factory practice,

(*f*) any chaff or dust except as a declared ingredient or as a recognized tolerance in a declared ingredient or

Minimum Protein Levels for Registered Feeds under Section 3

Kind or purpose of feed	Minimum level at which protein guarantee must be made Percentage
CATTLE FEEDS	
A Complete or ready to feed—	
Cows on pasture	13
Dry and freshening cows	13
Growing calves	13
Pregnant heifers	13
Bulls in service	13
Fattening steers	13
Cows in milk	15
B Supplements	24
C Basal feeds	11
SWINE FEEDS	
A Complete or ready to feed—	
Pig starter	17
Pig starter grower	16
Pig grower	15
Nursing and/or pregnant sows	15
Breeding gilts and boars	15
Hog finisher or fattener	13
B Supplements—	
Starter and/or sow	35
General purpose	35
CHICKEN FEEDS	
A Complete or ready to feed—	
1 Laying Mash—	
(a) Battery mash	14
(b) To be fed with scratch grains	16
2 Breeder or hatching mash	16
3 Chick starter mash	16
4 Broiler mash	17
5 Growing or range mash	15
6 Growing mash designated for confined birds	16
B Supplements—	
1 Laying or general purpose	32
2 Breeder or hatching mash	32
3 Chick starter	32
4 Growing	30
5 Broiler	32
6 Fattening	32
Chicken and/or Turkey Feeds (Poultry Feeds)	
Fattening or fleshing mash—	
(a) Complete type	14
(b) For mixing with milk	12

Kind or purpose of feed	Minimum level at which protein guarantee must be made
	Percentage
TURKEY FEEDS	
A Complete or ready to feed—	
1 Laying or breeder mash—	
(a) To be fed with scratch grains	18
(b) All mash type	15
2 Starting mash	24
3 Growing mash—	
(a) To be fed with scratch grains	18
(b) All mash	16
B Supplements—	
1 Laying hatching or breeder	35
2 Starter	35
3 Growing	35
DUCK FEEDS	
Complete or ready to feed—	
1 Laying or breeder mash	15
2 Starting mash	15
3 Growing mash	15
4 Fattening mash	15

(g) any other material in quantities likely to be deleterious to livestock

13 No chopped, crushed or ground feeding stuff shall contain more than fifteen vital seeds per ounce of any or all of the weeds listed in Table 3 of the Schedule hereto

Table 2

INJURIOUS MATERIALS UNDER SECTION 12 (1) (*a*)

Darnel
Purple cockle
Cow cockle
Wild mustard
False flax
Wormseed mustard
Stinkweed
Tumbling mustard
Hare's ear mustard
Ergotized grains

Definitions

Alfalfa Legume and Grass Meal

For the purposes of these regulations,

(*a*) "legume meal," "grass meal" or "legume-grass meal" is ground, unthreshed hay without the removal of leaves except as occurs naturally in hay making practice and without the addition of for-

Table 3

WEEDS UNDER SECTION 13	Hoary cress	Ragweed, false
Bladder campion	Johnson grass	Ragweed, great
Blue weed	Lamb's quarters	Ragweed, perennial
Canada thistle	Leafy spurge	Red cockle
Chicory	Mustard, ball	Redroot pigweed
Couch grass	Mustard, dog	Ribgrass
Cow Cockle	Mustard, hare's ear	Russian knapweed
Darnel	Mustard, tansy	Russian pigweed
Dock	Mustard, tumbling	Russian thistle
Dodder	Mustard, wild	Stickweed
Downy brome	Mustard, wormseed	Stinkweed
False Flax	Night flowering catch-fly	Toad flax
Field bindweed	Ox-eye daisy	White cockle
Field peppergrass	Perennial sow thistle	Wild carrot
Flixweed	Poverty weed	Wild radish
Forked catchfly	Purple cockle	Winter cress or yellow rocket
Halogeton	Ragweed, common	Yellow cress
Hoary alyssum		

eign material, it shall not contain more than 33 per cent of crude fiber,

(*b*) the conditions governing the use of the term "alfalfa" shall apply in like manner when another species is named,

(*c*) the general terms 'legume" or "grass" may be used in lieu of named species and no species shall be named which constitutes less than 25 per cent of a mixture,

(*d*) the term 'dehydrated" may be prefixed to the name of any legume meal, grass meal or legume grass meal, when the hay from which the meal was ground was dried rapidly by artificial heat,

(*e*) per cent" means per cent by weight

Alfalfa Meal consists of at least 75 per cent of alfalfa

Alfalfa Leaf Meal consists of at least 80 per cent of alfalfa leaves and shall not contain more than 18 per cent of crude fiber

Alfalfa Stem Meal consists of alfalfa from which leaves have been intentionally separated or which contains more than 33 per cent of crude fiber

Alfalfa Grass Meal consists of at least 50 per cent of alfalfa and at least 25 per cent of grasses

Legume-Grass Meal consists of at least 25 per cent of legumes and at least 25 per cent of grasses

Grass Meal consists of at least 75 per cent of grasses

Animal Products

Blood Meal is ground, dried blood

Feeding Tankage is the wet rendered or dry rendered, or both, residues from animal or poultry tissues suitable for feeding livestock and containing not less than 50 per cent of crude protein, it shall not contain more than 35 per cent of blood, if it is labelled with a name descriptive of its kind, composition or origin it shall correspond thereto, when wet-rendered it shall be tanked under live steam

A product otherwise as defined but containing less than 50 per cent of crude protein shall be labelled *Feeding Meat and Bone Tankage* provided that nothing shall be labelled as Feeding Meat and Bone Tankage which contains less than 40 per cent of crude protein

Meat Scrap or *Meat Meal* is the dry-rendered or open-kettle rendered, or both, residues from animal or poultry tissues suitable for feeding livestock, and containing not less than 50 per cent of crude protein, it shall be free from blood meal and shall contain only such traces of blood as may occur unavoidably in good factory practice when it is labelled with a name descriptive of its kind, composition or origin it shall correspond thereto

A product otherwise as defined but containing less than 50 per cent of crude protein shall be labelled *Meat and Bone Scrap* or *Meat and Bone Meal*, provided that nothing shall be labelled as Meat and Bone Scrap or Meat and Bone Meal which contains less than 40 per cent of crude protein

Feeding Bone Meal is the dried, ground product containing not less than 10 per cent of phosphorus (P) free from objectionable odour and of a quality suitable for feeding obtained from undecomposed bones which have been cooked to remove excess fat and meat

Feeding Steamed Bone Meal is the dried, ground product containing not less than 12 per cent of phosphorus (P), free from objectionable odour and of a quality suitable for feeding obtained from undecomposed bones which have been cooked with steam under pressure

Bone Char or Bone Black is the product obtained by charring bones in closed retorts

Animal Liver Meal is the product obtained by drying and grinding liver from slaughtered mammals

Animal Liver and Glandular Meal is the product obtained by drying and grinding liver and other glandular tissue from slaughtered mammals

Animal Fat is fat rendered from animal tissues, of a quality suitable for feeding, and may contain an antioxidant approved by the Food and Drug Regulations or by the Chief, Animal Pathology Division, Canada Department of Agriculture

Barley Products

Barley Feed is the entire by-product resulting from the manufacture of pot or pearl barley from clean barley.

Barley Mixed Feed is the entire offal from the milling of barley flour from clean barley, and is composed of barley hulls and barley middlings.

Beet Products

Dried Beet Pulp is the dried residue from sugar beets which have been cleaned and freed from crowns, leaves and dirt, and from which sugar has been extracted.

Brewers' and Distillers' Products

Brewers' Dried Grains is the dried, extracted residue of barley malt and/or other cereal grain or grain products, resulting from the manufacture of wort.

Brewers' Dried Yeast is the dried non-fermentive non-extracted yeast obtained as a by-product in the process of brewing.

Malt Sprouts is the product obtained by the removal of the sprouts from malted barley together with the malt hulls, other parts of malt and foreign material unavoidably present. Sprouts derived from any other cereal shall be designated by the name of that cereal (e.g. rye malt sprouts).

Corn Distillers' Dried Grains is the dried residue obtained in the manufacture of alcohol and distilled liquors from corn or a grain mixture in which corn predominates.

Rye Distillers' Dried Grains is the dried residue obtained in the manufacture of alcohol and distilled liquors from rye or a grain mixture in which rye predominates.

Wheat Distillers' Dried Grains is the dried residue obtained in the manufacture of alcohol and distilled liquors from wheat, or from a grain mixture in which wheat predominates.

NOTE: The term "With Solubles" may be added to the name of Distillers' Dried Grains which contains the major portion of the condensed screened stillage dried therewith.

Semi-Solid Distillers' Solubles is the product obtained in the manufacture of alcohol and distilled liquors from grain or molasses by condensing to a syrupy consistency the screened stillage obtained therefrom. When the source is indicated it shall correspond thereto.

Dried Distillers' Solubles is the product obtained by drying semi-solid Distillers' Solubles. When the source is indicated it shall correspond thereto.

than 9 per cent of oil from undecomposed, whole fish and/or fish cuttings

Oily Fish Meal is the clean, dried, ground residue, containing more than 9 per cent of oil from undecomposed, whole fish and/or fish cuttings.

Fish Residue Meal is the clean, dried, undecomposed residue from the manufacture of glue from non-oily fish

Whale Meal is the clean, dried, ground residue after the extraction of oil from undecomposed whale flesh

Cod Liver Meal is the clean dried, ground residue after the extraction of oil from undecomposed livers of the cod

NOTE Any of the above defined marine products
(*a*) which is designated as to the kind or type of fish employed in its manufacture shall correspond thereto,
(*b*) shall be free from any solvent
(c) shall include the percentage of salt as part of the brand or name when the salt content exceeds 4 per cent by weight (e g Fish Meal 6 per cent Salt)

Condensed Fish Solubles is the product obtained by condensing the solutions from the hydraulic process of oil extraction from fish

Cod Liver Oil is oil from the livers of the cod

Herring Oil is oil from whole herring or parts thereof

Menhaden Oil is oil from whole menhaden or parts thereof

Pilchard Oil or Sardine Oil is oil from whole Pacific pilchard or sardine or parts thereof

Salmon Oil is oil from salmon or parts thereof

Salmon Liver Oil is oil from the livers of salmon

Tuna Oil is oil from tuna or parts thereof

Oat Products

Oat Groats or Hulled Oats are oats with the hulls removed

Oatmeal or Rolled Oats is hulled oats or particles therefrom, obtained in the milling of table cereals and containing not more than 2 per cent of crude fiber

Oat Middlings is the by product containing not more than 4 per cent rude fiber, obtained in the milling of table cereals from clean oats

Oat Shorts is the by product containing not more than 7 per cent of crude fiber, obtained in the milling of table cereals from clean oats

Oat Feed is the by product containing not more than 22 per cent of crude fiber, obtained in the milling of table cereals from clean oats

Oat Hulls are the outer coverings of threshed oats and any by product obtained in the milling of table cereals from clean oats and containing more than 22 per cent of crude fiber shall be designated as "oat hulls"

Pea Products

Pea Bran is the coarse outer covering of threshed peas.

Peanut Products

Peanut Oil Cake is the residual product after the extraction of oil from peanut kernels.

Peanut Oil Meal is ground peanut oil cake.

Unhulled Peanut Oil Feed is the residual product after extraction of oil from whole peanuts.

Peanut Skins is the thin red-brown outer covering of the peanut kernel exclusive of hulls and may contain broken peanut kernels.

Peanut Meal or Ground Peanuts is ground peanut kernels and may contain peanut skios not exceeding the proportions in which they occur naturally.

Rice Products

Rice Bran is the pericarp or bran layer of rice, with only such quantity of hull fragments as is unavoidable in the regular milling of rice.

Rice Polish is the finely powdered material obtained in polishing rice kernels.

Rice Feed is the mill-run by-product obtained in the manufacture of polished rice from hulled rice, and consists of rice bran, rice polish and broken rice particles.

Rye Products

Rye Bran is the coarse, outer covering of the rye kernel as separated in the usual processes, other than scouring, of flour milling.

Rye Shorts consists of fine particles of bran, germ and a small proportion of low-grade or fibrous flour as separated in the usual processes of flour milling. It shall contain not more than 8 per cent of crude fiber.

Rye Middlings consists of a small proportion of fine bran particles, germ and a large proportion of low-grade or fibrous flour as separated in the usual processes of flour milling. It shall contain not more than 4·5 per cent of crude fiber.

Rye Feed is the mill-run by-product separated in the usual processes, other than cleaning or scouring, of flour milling.

Screening and Scourings

No. 1 Feed Screenings consists of wild buckwheat and broken and shrunken grain and may contain small proportions of other seeds of feed-

Buckwheat Products

Buckwheat Shorts or Buckwheat Middlings are the portions of the buckwheat grain immediately inside the hull, as separated from the flour

Cocoanut Products

Cocoanut Oil Meal or Copra Oil Meal is the ground residue after extraction of oil from the dried meat of the cocoanut

Corn Products

Corn Bran is the outer coating of the corn kernel, with little or none of the starchy part or the germ

Corn Feed Meal is the fine particles sifted from ground or cracked corn

Corn Grits or Hominy Grits are the fine or medium sized hard, flinty portions of sound Indian corn, with little or none of the bran or germ

Corn Gluten Feed is that part of commercial shelled corn that remains after the extraction of the larger part of the starch and germ by the processes employed in the wet milling manufacture of corn starch or corn syrup It may or may not contain either corn solubles or corn oil meal

Corn Gluten Meal is that part of commercial shelled corn that remains after the extraction of the larger part of the starch and germ, and the separation of the bran by the processes employed in the wet milling manufacture of corn starch or syrup It may or may not contain either corn solubles or corn oil meal

Maltose Process Corn Gluten Feed is the dried residue from degermed corn, after removal of the starch in the manufacture of malt syrup

Hominy Feed is a mixture of the bran germ and starchy part of corn as produced in the manufacture of pearl hominy, hominy grits or table meal and shall contain not less than 5 per cent of crude fat When prefixed with the words white or yellow, the product shall be from corn of the colour indicated

Corn Oil Cake is the residual product after extraction of oil from corn germ as separated in the wet milling process of manufacture of corn starch corn syrup and other corn products

Corn Oil Meal is ground corn oil cake

Corn Germ Cake is the residual product after extraction of oil from corn germ with other parts of the corn kernel as separated in the dry milling process of manufacture of corn meal corn grits hominy feed and other corn products

Corn Germ Meal is ground corn germ cake

Cottonseed Products

Cottonseed Cake is a product of the cottonseed only, containing not less than 36 per cent of crude protein and composed principally of the kernel with such portion of the hull as is necessary in the manufacture of oil If it be firm but not flinty in texture, of sweet odour, free from mould, and will produce a meal of prime quality, it may be designated "Cottonseed Cake, Prime Quality", otherwise it shall be designated 'Cottonseed Cake, Off Quality"

Cottonseed Meal is ground cottonseed cake If it be finely ground, of sweet odour, reasonably bright in colour, yellowish, not brown nor reddish, and free from excessive lint, it may be designated "Cottonseed Meal, Prime Quality", otherwise it shall be designated "Cottonseed Meal, Off Quality"

Cottonseed Feed is a mixture of cottonseed meal and cottonseed hulls, containing less than 36 per cent of crude protein

Whole Pressed Cottonseed is the product resulting from subjecting the whole, sound, mature, clean, undecorticated cottonseed to pressure for the extraction of oil, and includes the entire cottonseed less the oil extracted and the lint removed

Linseed and Flax Products

Linseed Cake or Oil Cake is the residual products, after extraction of oil from commercially pure flaxseed It shall not contain more than 0 5 per cent of acid insoluble ash, when the process employed in extracting the oil is designated, it shall correspond thereto

When ground, it shall be labelled *Linseed Oil Meal, Oil Cake Meal or Linseed Oilcake Meal*

Ground Flaxseed or Flaxseed Meal is the product obtained by grinding commercially pure flaxseed

Unscreened Flaxseed Oil Feed Cake is the residual product after extraction of oil from flaxseed which is not of commercial purity When ground it shall be so designated

Screenings Oil Feed is the residual product after the extraction of oil from flaxseed screenings

Marine Products

White Fish Meal is the clean, dried, ground residue, containing not more than 4 per cent of oil, from undecomposed, whole, non fatty, white-fleshed fish, including cod, haddock, hake, cusk, pollock, skates and monkfish, and/or cuttings thereof

Fish Meal is the clean, dried, ground residue, containing not more

ing value and wheat scourings It shall contain oot more than 7 per cent of crude fiber, oot more than 3 per cent of small weed seeds, cbaff and dust combined, not more than 5 per cent of ball mustard, not more than 6 per cent of small weed seeds chaff, dust and ball mustard combined, not more than 8 per cent of wild oats, and shall be cool and sweet

No 2 Feed Screenings is grain screenings witb or without wheat scourings and containing not more than 11 per cent of crude fiber, not more than 3 per cent of small weed seeds, chaff and dust combined, not more than 10 per cent of ball mustard, oot more than 10 per cent of small weed seeds, chaff, dust and ball mustard combined, not more than 49 per cent of wild oats, and shall be cool and sweet

Uncleaned Screenings is grain screenings excluded from tbe preceding grades or classes because of the content of weed seeds, cbaff or dust, but containing at least 35 per cent of material which, if separated, would classify as No 1 Feed Screenings

Refuse Screenings includes all classes of grain screenings excluded from the preceding grades or classes hecause of tbe cootent of weed seeds, chaff or dust

PROVIOED THAT

(*a*) whole (ungrouod) screenings, when sold uoder certificate of class or grade issued by an inspector appointed under the provisions of the Canada Grain Act, may bear the class or grade designation indicated in such certificate,

(*b*) screenings from small seeds, such as clovers and grasses, may he classified according to the crop seed from which obtained,

(*c*) No 1 Feed Screenings and No 2 Feed Screenings shall not contain more than one per ceot by weight of the materials listed in Table 2 of the Schedule hereto and an additional one per cent by weight of wild mustard and bare's ear mustard seeds,

(*d*) small weeds seeds shall he those capable of passing through a 4½/64 incb round perforation.

Scourings consist of such portions of tbe cuticle, brusb, white caps and other materials as are separated from grain in tbe usual commercial process of scouring

Soybean Products

Soybean Oil Cake or Soybean Oil Chips is the residual product after extraction of oil from soybeans

Soybean Oil Meal is ground soybean oil cake or ground soybean oil chips

Wheat Prodocts

Bran is the coarse, outer covering of the wheat kernel as separated in the usual processes other than scouring of flour milling

This association issues annually its official publication, in which is given a wealth of information relative to the control of the commerce of feedstuffs It includes such items as official regulations concerning naming of *ingredients, registration, labelling, weights of packages,* use of preservatives, etc , as well as resolutions expressing the official attitude on a wide variety of matters incidental to feeding stuffs legislation and regulation There is also a section giving official definition of feeding stuffs Another section is given over to a presentation of a considerable number of analytical procedures of the Association of Official Agricultural Chemists ' to be used as a guide and a source of ready reference in the analysis of feedstuffs " The list is not exhaustive but covers those techniques necessary for the more fundamental examination of feedstuffs To one wishing an insight into the problems and the workings of the machinery of Feeding Stuffs Control these publications are invaluable They are obtainable from the Executive Secretary, L E Bopst, College Park, Maryland, for the sum of $5 00

Actual feed legislation in the United States is entirely a State responsibility As a consequence, feed legislation is not the same in all states One of the objectives of the A A F C O has been the unification of feed legislation and in this connection they have, through a standing committee, designed a *Model Feed Bill* as a guide to what they believe such legislation should embrace Excerpts from it are presented in the following paragraphs

Excerpts from the

Proposed Uniform State Feed Bill

Section 4. Registration

a Each brand of commercial feed shall be registered before being offered for sale, sold or otherwise distributed in this state The application [for registration] shall include the following information

1 The name and principal address of the person responsible for distributing the commercial feed
2 The name or brand under which the commercial feed is to be sold

3 The guaranteed analysis, listing the minimum percentage of crude protein, minimum percentage of crude fat, and maximum percentage of crude fiber. For mineral feeds the list shall include the following if added Minimum and maximum percentage of calcium (Ca), minimum percentage of phosphorus (P), minimum percentage of iodine (I), and minimum and maximum percentages of salt (NaCl) Other substances or elements, determinable by laboratory methods, may be guaranteed by permission of or by requirement by regulation of the __________ with the advice of the Director of the Agricultural Experiment Station When any such other items are guaranteed, they shall be subject to inspection and analysis in accordance with the methods and regulations that may be prescribed by __________ Products sold solely as mineral and/or vitamin supplements and guaranteed as specified in this Section need not show guarantees for protein, fat and fiber

4 The common or usual English name of each ingredient used in the manufacture of the commercial feed, except as the __________ shall regulate otherwise"

Section 7. Adulteration

No person shall distribute an adulterated commercial feed A commercial feed or customer-formula feed shall be deemed to be adulterated

a If any poisonous, deleterious or non-nutritive ingredient has been added in sufficient amount to render it injurious to animal health
b If any valuable constituent has been in whole or part omitted or abstracted therefrom or any less valuable substance substituted therefor
c If its composition or quality falls below or differs from that which it is purported or is represented to possess by its labeling
d If it contains added hulls, screenings, straw, cobs, or other high fiber material unless the name of each such material is clearly and prominently stated on the label

Sectinn 7. Misbranding

No person shall distribute misbranded feed A commercial feed or customer-formula feed shall be deemed to be misbranded

a If its labeling is false or misleading in any particular.
b If it is distributed under the name of another feed
c If it is not labeled as required in Section 5 of this Act and in regulations prescribed under this Act
d If it purports to be or is represented as a feed ingredient, or if it purports to contain or is represented as containing a feed ingredient, unless such feed ingredient conforms to the definition of identity, if

any, prescribed by regulation of the ________, in the adopting of such regulations the ________ shall give due regard to commonly accepted definitions such as those issued by the Association of American Feed Control Officials

e If any word statement, or other information required by or under authority of this Act to appear on the label or labeling is not prominently placed thereon with such conspicuousness (as compared with other words, statements, designs, or devices, in the labeling) and in such terms as to render it likely to be read and understood by the ordinary individual under customary conditions of purchase and use

Excerpts from the

Rules and Regulations Under the Uniform State Feed Bill

1 Brand Names

(a) The name of a brand must not tend to mislead the purchaser with respect to the quality of the feed If the brand name indicates the feed is made for a specific use the character of the feed must conform therewith A mixture labeled "dairy feed,' for example, must be adapted for that purpose

(b) A brand name of a non medicated feed shall not be derived from one or more ingredients of a mixture to the exclusion of other ingredients A distinctive name shall not be one representing any component of a mixture

(c) The word vitamin, or a contraction thereof, or any word suggesting vitamin can be used only in the brand name of a feed which is represented to be a vitamin supplement and which is labeled with the minimum vitamin content as specified in Regulation 2(c)

(d) The term mineralized' shall not be used in the brand name of a feed except 'Trace Mineralized Salt" When so used, the produce must contain significant amounts of trace minerals which are recognized as essential for the nutrition of farm animals The ingredients shall be stated in the form in which used

(e) When the brand name carries a percentage value it shall be understood to signify protein content If any other percentage values are used in brand names they must be followed by the proper description

2. *Expression of Guarantees.*
   (a) The sliding-scale method of expressing guarantees (for example, "Protein 15-18%") is prohibited.
   (b) Drugs and hormones in commercial feeds shall be guaranteed in terms of percentage by weight; antibiotics in terms of grams per pound of feed.
   (c) Vitamins, when guaranteed, shall be expressed in milligrams per pound of feed, except that Vitamin A, other than precursors of vitamin A, shall be stated in USP units; Vitamin D, in products offered for poultry feeding, in International Chick units; vitamin D for other uses, in USP units; vitamin E in a Vitamin E supplement, in International Units per pound of feed.
   (d) Minerals, except salt (NaCl) when guaranteed, shall be stated in terms of percentage of the element.

3. *Ingredient Statement.*
   (a) Each ingredient must be specifically named. When an ingredient has no common or usual English name, the names and definitions adopted by the Association of American Feed Control Officials are to be used unless the ________ designates otherwise.
   (b) When water is added in the preparation of canned foods for animals, water must be listed as an ingredient.
   (c) The term "dehydrated" may precede the name of any product that has been artificially dried.
   (d) No reference to quality or grade of an ingredient shall appear in the ingredient statement of a feed.

4. *Labeling.*
   (a) The information required in Section 5(A) of the law must appear in its entirety on one side of a label or on one side of the container.
   (b) The names of all ingredients must be shown in letters or type of the same size.

5. *Minerals.*
   (a) When the word "iodized" is used in connection with a feed ingredient, the ingredient shall not contain less than 0.007% iodine, uniformly distributed.
   (b) Mineral phosphatic materials for feeding purposes shall be labeled with a guarantee for the minimum percentages of calcium and phosphorus, and the maximum percentage of fluorine.
   (c) The fluorine content of any mineral or mineral mixture which is to be used directly for the feeding of domestic

animals shall not exceed 0 30 per cent for cattle, 0 35 per cent for sheep 0 45 per cent for swine, and 0 60 per cent for poultry

Soft phosphate with colloidal clay, rock phosphates or other fluorine-bearing ingredients may be used only in such amounts that they will not raise the fluorine concentration of the total (grain) ration above the following amounts 0 009 per cent for cattle, 0 01 per cent for sheep, 0 014 per cent for swine, and 0 035 per cent for poultry

6 *Urea*

(a) Urea and ammonium salts of carbonic and phosphoric acids are acceptable ingredients in proprietary cattle, sheep and goat feeds only, these materials shall be considered adulterants in proprietary feeds for other animals and birds, the maximum percentage of equivalent protein from non protein nitrogen must appear immediately below crude protein in the chemical guarantee, and the name of the substance supplying the non protein nitrogen must appear in the ingredient list If feed contains more than 3 per cent of urea, or if the equivalent protein contributed by urea exceeds one third of the total crude protein, the label shall bear (1) a statement of proper usage and (2) the following statement in type of such conspicuousness as to render it likely to be read and understood by ordinary individuals under customary conditions of purchase and use

WARNING This feed should be used only in accordance with directions furnished on the label

7 *Artificial Color*

(a) An artificial color may be used in feeds only if it has been shown to be harmless to animals No material shall be used to enhance the natural color of a feed or feed ingredient whereby inferiority would be concealed

8 *Drugs hormones etc*

Before a registration is accepted for a commercial feed which contains drugs hormones, or other ingredients which are potentially harmful to animals, the distributor may be required (1) to submit evidence to show the safety of the feed when used according to the directions which the distributor furnishes with the feed (2) to furnish a written statement that adequate written or printed warnings and feeding directions will accompany each delivery of feed, (3) to state the percentage of the drug hormone, or other ingredients in a prominent place on the label of the feed

9 *Weed Seeds*

When weed seeds are contained in commercial feeds, their viability must be destroyed by fine grinding or by other means

APPENDIX 3

Miscellaneous Tables and Charts

Tables of Feed Composition

It would be interesting to know how many sets of analytical figures have been compiled on feeding stuffs even during the past 10 years. The number would be fantastic if we included only data for the proximate analysis. Yet, in spite of this fact, there is available almost no reliable information as to the sample to sample variation that exists for feeds called by the same name. We have numerous compilations of chemical analysis figures of the common feeds, but these figures are, for each item recorded, merely the averages of whatever individual samples were included. The better known tables, such as those of Morrison or Schneider, indicate the number of analyses that were averaged to give the figures presented, and for some feeds the number is large. For example, Morrison has averaged over 10,000 figures to arrive at the composition of cottonseed meal. For some feeds, however, only one or two sets of figures have been available on which to base the average composition.

Such wide disparity raises a fundamental question regarding all tables of food or feed composition. What do such tables tell about a feed that is useful to the nutritionist or the feeder?

At the outset it will, of course, be obvious that tables of average analyses describe what is likely to be found in other samples of those feeds. This meaning is something different from the implication often read into the figures: that other samples individually will have the same makeup as the average shown in the table. By definition aver-

ages are the best single statistical statements of the most likely value of samples chosen at random from all relevant figures But it is also true that where relatively few figures are available their calculated average may not represent any one of the values at hand

This statement makes it obvious that it is not good judgment to assume, for example, that the composition of any given samples of cottonseed meal will analyse

Crude protein	43 2%
Crude fat	7 2
Crude fiber	10 6

in spite of the fact that these were the mathematical averages of 10,098 samples of 43% grade cottonseed meal

According to calculations of Frapps* the standard deviations applicable to protein, fat, and fiber analyses of feeds are about 10, 15, and 18%, respectively, which means that for two samples out of three the analyses might be expected to lie between

Protein	38 9-47 5%
Fat	6 1- 8 3
Fiber	8 7 12 5

We do not mean to say that if you examined a number of samples their average values would not be those shown in the table but we do want to point out that specific single samples can be expected to differ from even the most reliable average by an appreciable amount

The significance of this fact is that in the formulation of rations from tables of feed analyses, the calculated composition of the mixture may not agree with the figures obtained by actual analysis of a sample of the feed mixture The discrepancy will be largely the effect of the deviation of each feed involved from the average given in the table used in the calculation The error will be smaller as the number of feeds used is increased since in any one case the discrepancy is equally likely to be above as below tbe average

With feeds where but a few analyses are used in the averages, a second difficulty arises We are not sure the table average is a

* *Texas Bulletin 461*

true statement of the proper figure. And if the table average is not the real average, then we cannot apply an average standard deviation with confidence that it will give us the true limits above and below the table averages within which we can expect to find individual samples.

This problem is discussed here for two reasons. First, everyone working with feeds uses tables of feed composition. But unfortunately such tables do not at present give any indication of the variation that is characteristic of any particular nutrient between different samples of a feedstuff. And, as a consequence, the table user may neglect to take the variation into account in dealing with ration formulation.

The second reason for discussing the problem concerns the data itself of such tables. Here we may be justified in considering two purposes that such data serve. The one is as an accurate record of the nutrient composition of feeds based on as extensive sampling as can be arranged in accordance with sound statistical considerations of sampling. Such tables are in course of preparation by a Committee on Feed Composition of the U.S. Research Council. These are the basic reference tables covering all feedstuffs and all of the nutrients and other chemical fractions of nutritional interest and significance. They are to be available in pamphlet form similar to the series of booklets of Nutrient Requirements of animals. With such tables readily available it is obviously unnecessary to encumber texts on feeds and feeding with any such extensive feed descriptions.

A second type of table can be thought of as a working table whose purpose it is to define feeds with sufficient accuracy to enable the animal husbandman to use them properly in ration formulation. For such a purpose we must know the approximate content of the proximate principles, and of such minerals and vitamins as we may need to consider specifically in the preparation of balanced rations.

The protein figure establishes the category of the feed, as based on protein; the fiber, nitrogen-free extract, TDN and digestible caloric figures are guides as to relative energy value; fat is indicative of energy value also; but, in addition, the figure for fat is of use in predicting the stability of the feed in storage. This type of information

TABLE Ap-6 *Selected List of Common Concentrate Feeds with Typical*

Feedstuffs	Crude protein		Crude fat	Crude fiber	Generally used TON		Calcium	Phosphorus	VITAMINS	
	Total %	Dig %	%	%	Cattle %	Swine %	%	%	Thiamine mg/lb.	Riboflavin mg/lb.
Basal Feeds										
Barley	13	11	2	6	71	70	0.05	0.38	2.5	0.5
Buckwheat	12	9	2	10	64	68	0.04	0.29	2.3	0.3
Corn	10	7	4	2	80	80	0.01	0.28	2.1	6.0
Hominy feed	11	7	7	4	85	80	0.03	0.57	3.8	0.9
Kafir	11	9	3	2	81		0.04	0.33	1.6	0.5
Milo	11	9	3	2	80		0.03	0.27	1.8	0.4
Oats	12	10	5	11	66	65	0.09	0.33	3.5	0.5
Oat groats	14	11	8	1			0.09	0.44	2.5	0.5
Rice	12	7	12	9	71		0.07	0.21	1.2	0.6
Rice feed	12		16	7	71				8.9	1.2
Rye	13	10	2	2	76		0.04	0.16	2.0	0.7
Wheat	15	11	2	4	83	81	0.03	0.43	2.3	5.0
Wheat bran	16	13	4	10	66	57	0.14	1.30	3.5	1.2
Wheat shorts	17	13	5	7		71	0.08	0.94	6.0	1.3
Protein Supplements										
Plant Origin										
Cottonseed meal	41	36	5	13	79	75	0.20	1.19	5.8	1.5
Distillers grain (corn)	27	20	11	12	81		0.04	0.29	2.0	3.5
Gluten feed (corn)	25	21	3	8	75		0.14	0.55		1.5
Linseed oilmeal	36	34	5	9	76	68	0.36	0.74	5.9	1.5
Malt sprouts	23	17	1	16	70		0.24	0.71		4.3
Peanut oilmeal	44	48	5	4	80	82	0.17	0.55	3.0	0.2
Soybean oilmeal	44	36	4	7	73	74	0.28	0.66	4.0	1.5
Animal Origin										
Fish meal	66	60	2	1		62	4.24	3.06	0.5	3.0
Meat meal	51	45	11	2		79	10.00	5.00	0.1	2.5
Skimmilk powder	35	31	1	0		86	1.27	0.10	1.6	7.0
Tankage	50	46	11	2		67	6.21	3.42	0.4	0.7
Miscellaneous										
Alfalfa or grass meal	12	11	2	30	52	33	1.31	0.17	2.0	6.5
Dried brewers' yeast	47		3	1	75	65	1.26	1.21	25.0	16.0
Distillers solubles	27	20	8	3	75		0.35	1.40	3.8	10.2
Molasses (cane)	3	1			72	58	0.56	0.06	0.5	1.0

Nutrient Composition

VITAMINS (Continued)				AMINO ACIDS (as % of dry feeds)									
Pantothenic acid mg/lb	Niacin mg/lb	Vitamin A Iu/lb	Carotene mg/lb	Arginine %	Histidine %	Isoleucine %	Leucine %	Lysine %	Methionine %	Phenylalanine %	Threonine %	Tryptophane %	Val ne %
3 2	30	0		0 48	0 18	0 43	0 61	0 18	0 29	0 44	0 25	0 11	0 4
07	20	0											
3 2	10	3,100	1 3	0 34	0 28	0 55	1 80	0 20	0 25	0 66	0 49	0 06	0 6
3 5	9	800	4 1										
57	18												
6 0	13												
4 5	3	0		0 60	0 29	0 50	0 72	0 33	0 23	0 52	0 33	0 13	0 5
4.7	8	0		1 13	0 34	0 68	1 19	0 46	0 16	0 71	0 56	0 16	0 81
	13	0		0 61	0 16	0 31	0 60	0 19	0 10	0 34	0 25	0 06	0 44
	170	0		0 48	0 14	0 38	0 52	0 43		0 35	0 27	0 11	0 56
4 2	7												
5 0	20	0		0 40	0 35	0 62	1 02	0 28	0 13	0.70	0 51	0 11	0 71
11 3	110	175		96	42	60	86	53	19	51	33	24	77
6 0	43	175											
5 0	20	150	0 1	3 20	1 10	1 60	2 10	1 20	0.72	2 20	1 20	0 47	1 80
5 0	38	1,100		0.77	0 69	1 70	2 10	0 60	0 43	1 80	0 94	0 10	1 50
4.5	47	1 000	6 1	0 61	0 63	1 10	2 80	0 68	0 25	0 90	0 88	0 14	1 30
3 2	24	0	0 1	2 20	0 51	1 40	2 10	0 90	0.71	1.70	1 60	0 53	1 90
	25												
24 0	75	0	0 1	4 40	0 86	1 40	2 40	1 30	0 57	2 20	0 62	0 42	2 30
6 3	10	0	0 1	2 80	1 00	2 10	3 00	2.70	0.79	2 10	1 70	0.53	2 00
24 0	27	0		3 80	1 50	3 20	4 90	3.70	1 90	2.70	2 60	0.78	3 10
2 3	24	0		3 15	1 40	2 44	4 04	3 30	0 94	2 43	1 90	0.34	3 00
15 0	4	0		1 40	1 10	2 20	3 20	2 60	1 00	1 60	1 40	0 46	2.40
0 8	25	0		2 99	1 33	1 60	4 20	2.79	0.53	2 25	1.58	0 37	2.74
17 0	13	33,000	36 0	1 10	0 36	0 87	1.30	0 85	0.39	0 87	0 68	0.32	1 00
50 0	200	0		1 93	0 67	2 03	2.78	2 99	0 45	1.53	2 17	0 38	2 17
12 0	45	0											
22 0	21	0											

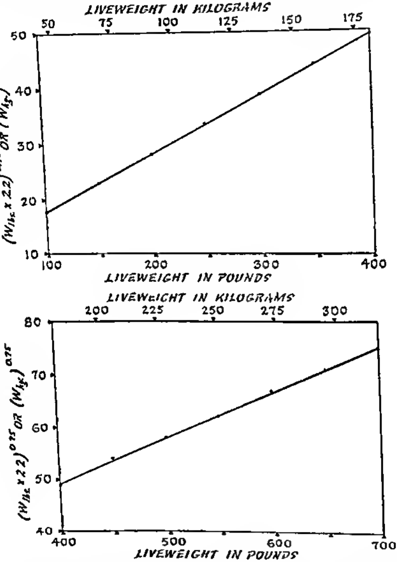
TABLE Ap-7 *Selected List of Roughage Feeds with Typical Nutrient Composition*

Feedstuffs	Crude Protein Total %	Crude Protein Dig %	Fiber %	% TDN Cattle	Calcium %	Calcium gm/lb	Phosphorus %	Phosphorus gm/lb	Carotene mg/lb
Dry Hays and Fodders									
Alfalfa all analyses	15	11	29	50	1.47	6.67	0.24	1.09	11.4
Alfalfa past bloom	13	9	32	48					3.2
Barley	12	4	25	52	0.26	1.18	0.23	1.04	
Birdsfoot trefoil	14	10	28	51	1.13	5.13	0.22	1.00	
Bromegrass	10	5	28	49	0.20	0.91	0.28	1.27	
Clover alsike	12	8	27	53	1.15	5.22	0.23	1.04	
Clover ladino	19	14	21	55	1.32	5.99	0.29	1.32	
Clover red	12	7	27	52	1.35	6.13	0.19	0.86	8.6
Clover and timothy	9	5	30	51	0.68	3.09	0.20	0.91	
Corncobs ground	2	0	32	46			0.02	0.09	
Corn fodder	7	3	22	54	0.21	0.95	0.14	0.64	1.8
Corn stover	6	2	27	46	0.26	1.18	0.05	0.23	
Cowpea	19	12	23	51	1.37	6.22	0.29	1.32	
Kafir fodder	9	5	26	54	0.35	1.59	0.18	0.82	2.0
Kafir stover	6	2	30	51	0.54	2.45	0.09	0.41	1.1
Lespedeza immature	14	7	23	49	1.04	4.72	0.19	0.86	22.4
Lespedeza mature	12	4	33	40	0.90	4.09	0.15	0.68	
Mixed good	8	4	31	50	0.61	2.77	0.18	0.82	
Oat	8	5	28	47	0.21	0.95	0.19	0.86	
Prairie western	6	2	30	50	0.36	1.63	0.18	0.82	9.3
Sorghum fodder sweet	6	3	25	52	0.34	1.54	0.12	0.54	1.1
Soybean	14	10	28	49	0.94	4.27	0.24	1.09	
Soybean in bloom	17	12	21	52	1.53	6.95	0.27	1.23	
Soybean seed ripe	15	11	24	55	0.86	3.90	0.32	1.45	3.0
Sudan grass	9	4	28	49	0.36	1.63	0.26	1.18	
Timothy	7	3	30	49	0.23	1.04	0.20	0.91	5.3
Timothy before bloom	10	5	27	57					9.2
Timothy full bloom	6	3	30	48	0.23	1.04	0.20	0.91	4.2
Timothy late seed	5	2	31	42	0.14	0.64	0.15	0.68	2.5
Wheat	6	3	26	47	0.14	0.64	0.18	0.82	

TABLE Ap-7 *Selected List of Roughage Feeds with Typical Nutrient Composition (Continued)*

Feedstuffs	Total Dry matter	Crude Protein Total %	Crude Protein Dig %	Fiber %	% TDN cattle	Calcium %	Calcium gm/lb	Phosphorus %	Phosphorus gm/lb	Carotene mg/lb
Straw										
Barley		4	1	38	42	0 32	1 45	0 11	0 50	
Oat		4	1	36	45	0 19	0 86	0 10	0 45	
Soybean		4	1	41	39			0 13	0 59	
Wheat		4	1	37	41	0 21	0 95	0 07	0 32	
Silage										
Alfalfa, no preservative	25	4	3	8	14	0 35	1 59	0 08	0 36	21 1
Alfalfa molasses	27	4	3	8	15	0 41	1 86	0 08	0 36	14 5
Beet top	32	4	3	4	15	0 31	1 41	0 07	0 32	5 1
Clover, ladino and timothy	30	6	4	7	18	0 36	1 63	0 06	0 27	22 3
Corn, dent, well matured	27	2	1	7	18	0 10	0 45	0 06	0.27	6 4
Corn, dent, immature	20	2	1	6	13					
Corn and soybeans, well matured	28	3	2	7	20	0 20	0 91	0 08	0 36	
Grass silage, high legumes	33	5	3	9	19					24.3
Grass silage, low legumes, molasses	29	3	2	9	18			0 07	0.32	
Sorghum, sweet	25	2	1	7	15	0 08	0 36	0 04	0 18	2.7
Soybean	25	4	3	7	15	0 34	1.54	0 09	0 41	14 6
Sudan grass	26	2	2	9	15					
Timothy (wilted)	30	3	2	10	18	0 18	0 82	0 09	0.41	14 1
Timothy, molasses	43	4	2	14	17	0 16	0.73	0 08	0.36	

CHART AP-C. *Four Graphs Illustrating the Conversion of Live*

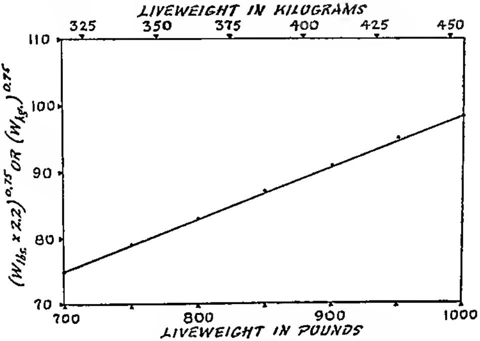


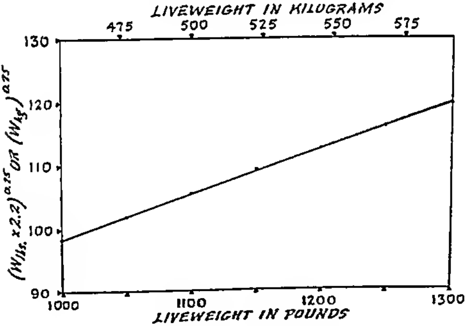
The metabolic size of animals is that weight to which their energy and most of their nutrient needs are related. It is expressed as the body weight in kilograms raised to the three-quarter power ($W_{kg}^{0.75}$) or [$(W_{lbs} \times 2.2)^{0.75}$]

This value can be written for calculation in two ways. If logarithms are to be used the solution is Antilog of ($\log W \times 0.75$)

Arithmetically it may be written

Weight of Animals to Their Metabolic Size





$$\sqrt[4]{w.^3} \quad \text{or} \quad \sqrt[2]{\sqrt[2]{w.^3}}$$

which indicates that the answer is obtained as the square root of the square root of the number resulting from multiplying the weight by its square.

For most uses in nutrition the number representing the metabolic size of an animal may, with sufficient accuracy, be read from the graphs above.

CHART Ap-D *Conversion of Ppm to Mgs per Day per Kg of Body Weight*

In dealing with trace elements or other ration amendments sometimes described in ppm it may be desirable to translate such figures to weight units The relationships are such that:

$$\text{Milligrams intake per day per kg body weight} = \frac{\text{ppm} \times \text{lbs of feed per day}}{\text{lbs wt of animal}}$$

Example A 900 lb cow receiving daily 20 lbs feed which contains 90 ppm fluorine

$$\left[\frac{90}{\cancel{1,000\,000}} \times \frac{20 \times \cancel{1,000\,000}}{\cancel{2.2}} \times \frac{\cancel{2.2}}{900}\right] = \frac{90 \times 20}{900} = 0\ 2 \text{ mg/kg/day of fluorine}$$

does not demand figures carried to the limit of their analytical accuracy In fact, such accuracy defeats the primary usefulness of the data—that of a practical or working description of the feedstuff

Those who have had experience in the formulation of commercial feed mixtures have learned that such refinements of quantitative analytical data are not practically useful Feed regulations never demand, nor could they enforce, requirements as to guarantees of protein, fat, or fiber to an accuracy of a fraction of a per cent Above all, the animal itself does show by altered performance, that fluctuations in nutrient intake of the order involved in *usual* sample variation are of significance

Our conclusion from both the theoretical and the practical viewpoints is that tables of feed composition most useful as guides in ration formulation should not affect an analytical accuracy beyond that given by expressing the proximate principles as whole percentages the calcium and phosphorus to one tenth, and trace minerals

CHART Ap-E *Weight Conversions*

Micrograms	× 1000	= milligrams
Milligrams	× 1000	= grams
Grams	× 1000	= kilograms
Grams	× 28 3	= ounces
Grams	× 454	= pounds
Ounces	× 16	= pounds
Kilograms	× 2 2	= pounds

and vitamins to one one-hundredth of one per cent. In general, those nutrients or fractions normally expressed in units of kilograms or pounds need no decimals in the percentage figures, and those measured in ounces or grams, only one place of decimals. Nutrients referred to in milligrams usually need two or sometimes three decimals if they are to be shown as percentages. When the nutrient occurs in less than a milligram per pound, parts per million (ppm.) may be a preferred descriptive value.

The tables of feed composition given here are working tables in the above sense. They are obviously not exhaustive but include the common widely used feedstuffs. They will be as accurate as such tables need to be for the practical manipulation of feedstuffs in applied feeding. As such they will be adequate for instructional purposes as well (see Table Ap-6 and Table Ap-7).

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